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Hirota et al.

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(45) **Date of Patent: Sep. 4, 2012**

(54) **IMAGE FORMING APPARATUS WITH DEVELOPER PASSAGE AMOUNT CONTROL ELECTRODES**

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(73) Assignee: **Ricoh Company, Limited**, Tokyo (JP)

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(21) Appl. No.: **12/707,124**

(22) Filed: **Feb. 17, 2010**

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(30) **Foreign Application Priority Data**

Feb. 25, 2009 (JP) 2009-042846

(51) **Int. Cl.**
B41J 2/00 (2006.01)

(52) **U.S. Cl.** **347/151**

(58) **Field of Classification Search** 347/151, 347/55, 43, 111, 112, 115, 139, 148; 399/168, 399/223, 235, 236, 241, 291, 293, 295–298, 399/302, 310

See application file for complete search history.

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Primary Examiner — Kristal Feggins

(74) *Attorney, Agent, or Firm* — Oblon, Spivak, McClelland, Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

An image forming apparatus comprises a toner-bearing member that bears toner and makes the toner clouded thereon. A toner passage control device including plural widthwise lines of toner passage holes in a printing medium conveyance direction is provided. Each of the toner passage holes includes a control electrode that controls passage of the toner through each of the toner passage holes toward a printing medium. a control pulse proving device provides a control pulse to the control electrode to operate. The control pulse applied to the control electrode of the one of the plural lines is different from that applied to the control electrode of the other one of the plural lines.

6 Claims, 13 Drawing Sheets

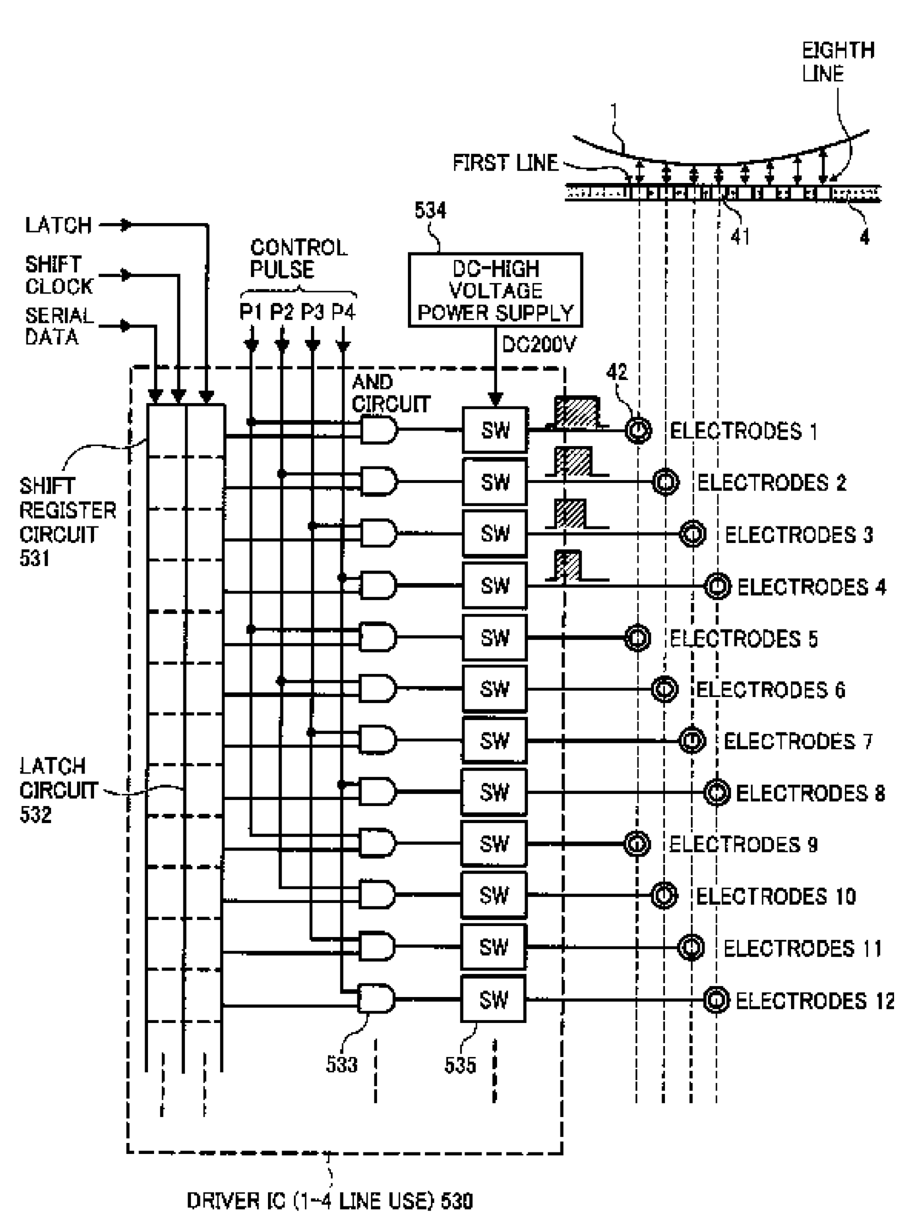

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FIG. 1

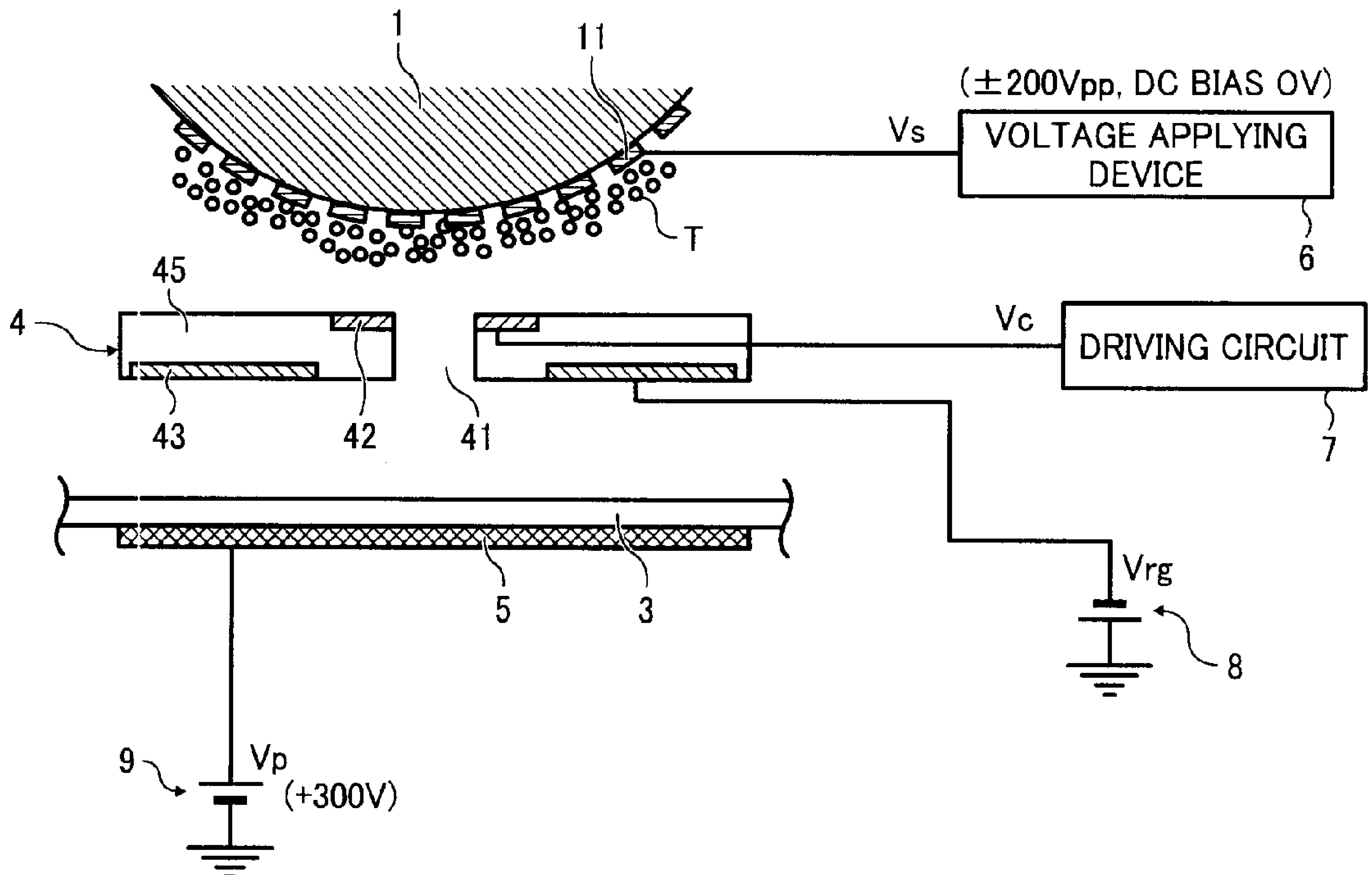
1
11
(±200Vpp, DC BIAS 0V)
Vs
VOLTAGE APPLYING DEVICE
T
6
45
4
Vc
DRIVING CIRCUIT
43
42
41
7
Vrg
5
3
8
9
Vp
(+300V)

FIG. 2

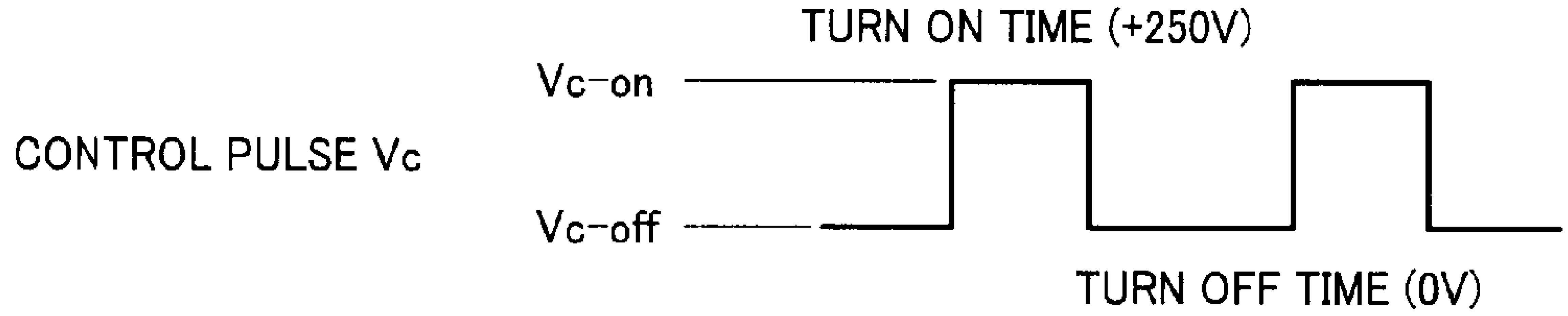
TURN ON TIME (+250V)
Vc-on
CONTROL PULSE Vc
Vc-off
TURN OFF TIME (0V)

FIG. 3A

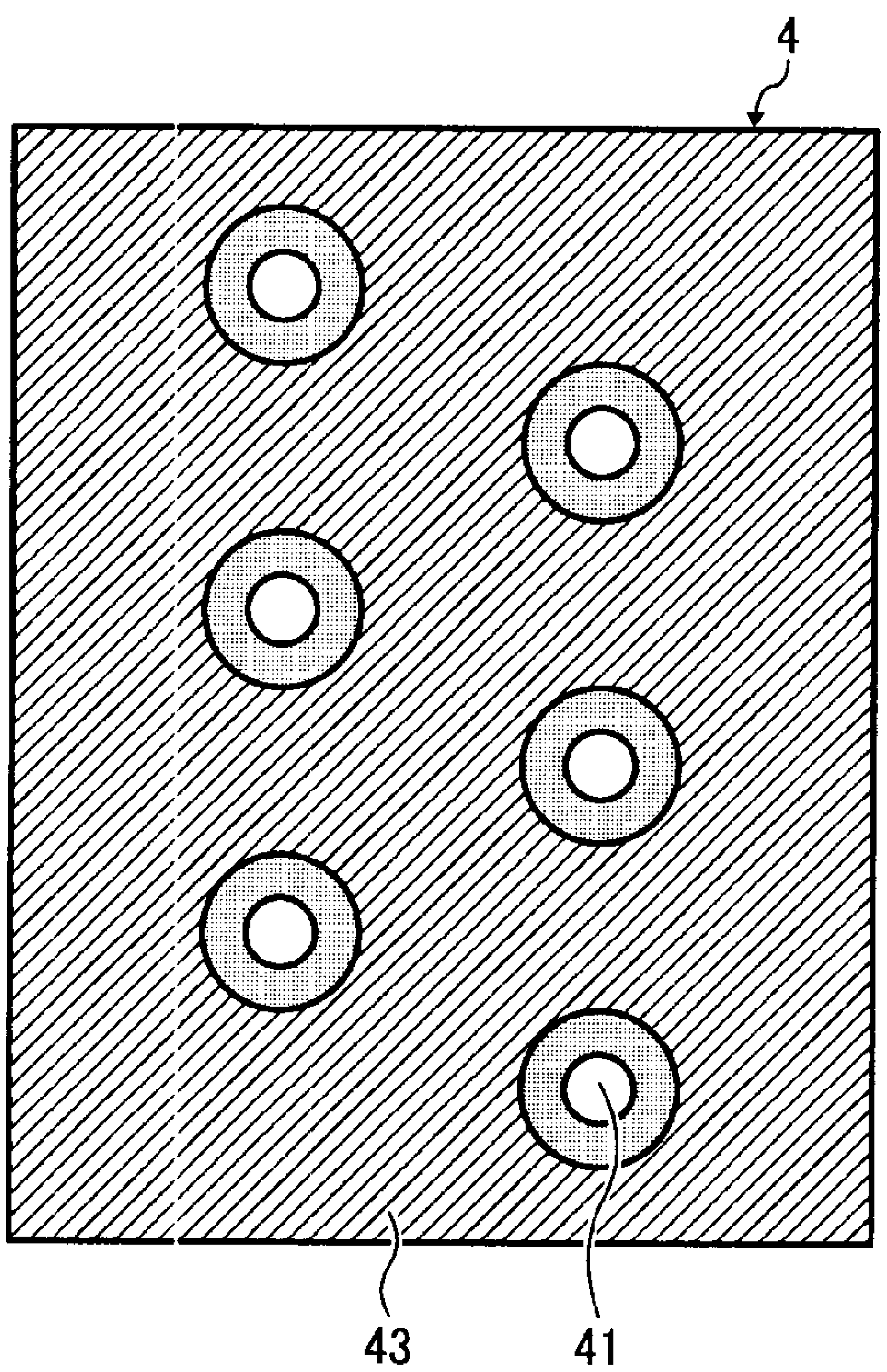

FIG. 3B

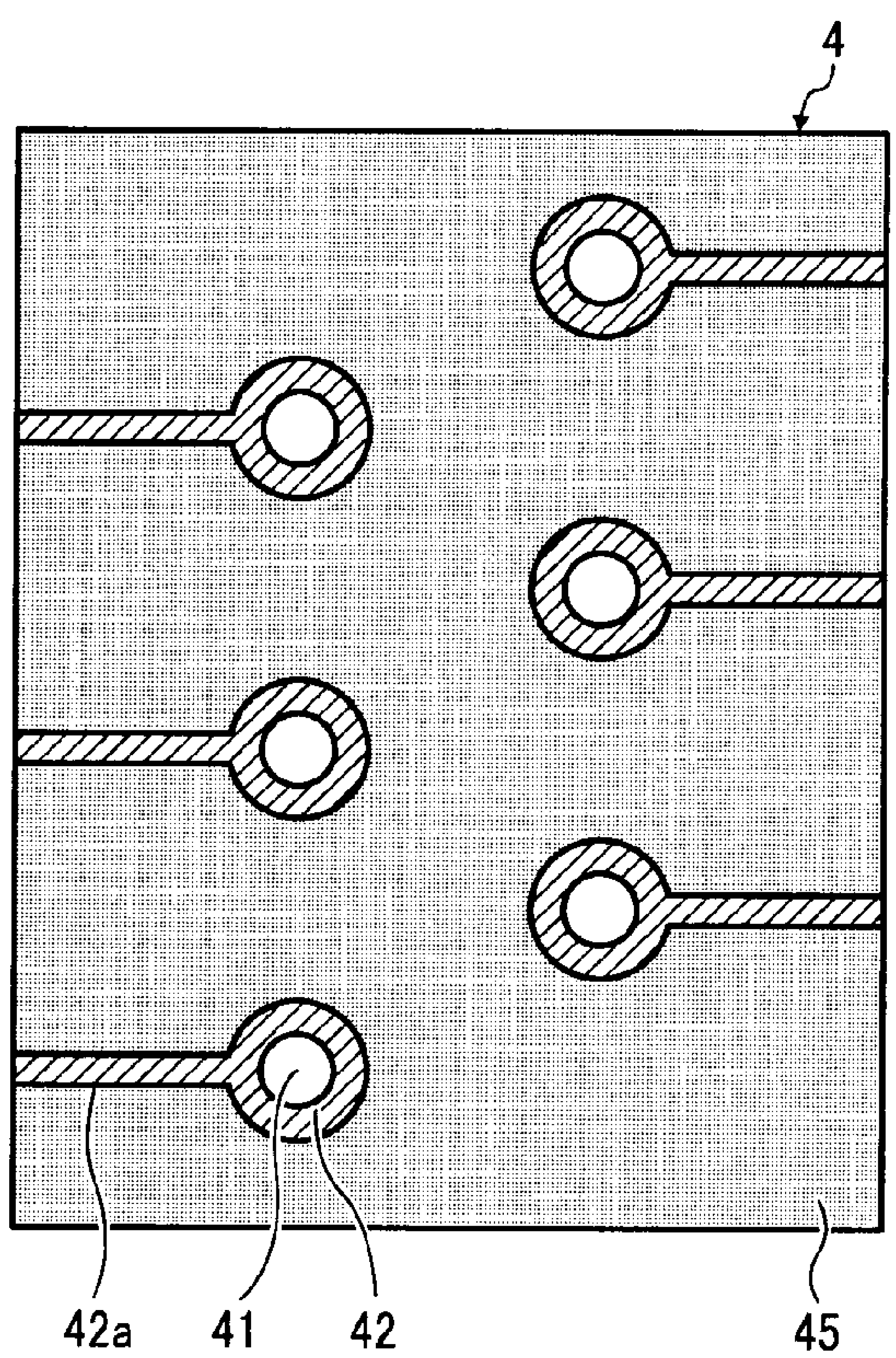

FIG. 4A

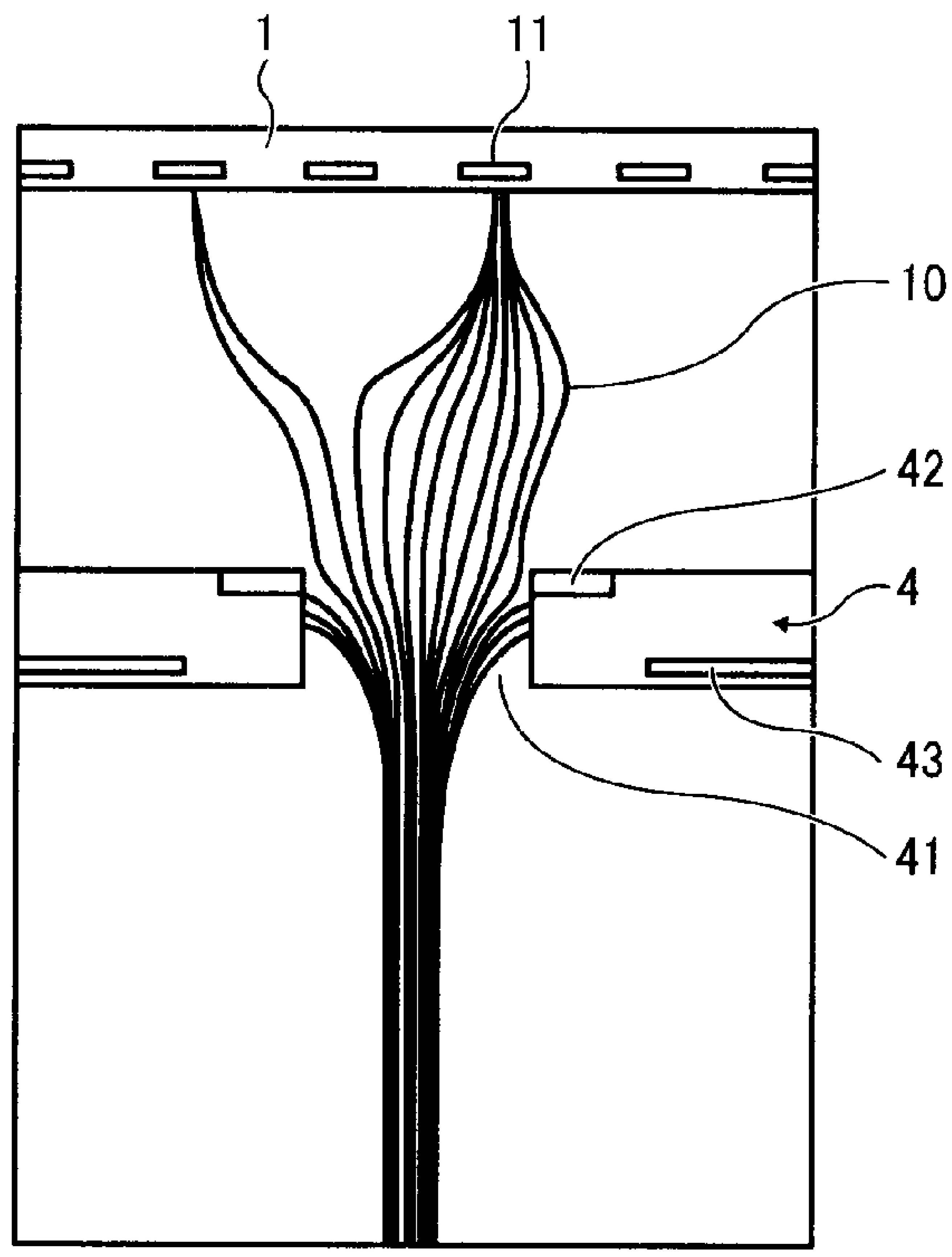

FIG. 4B

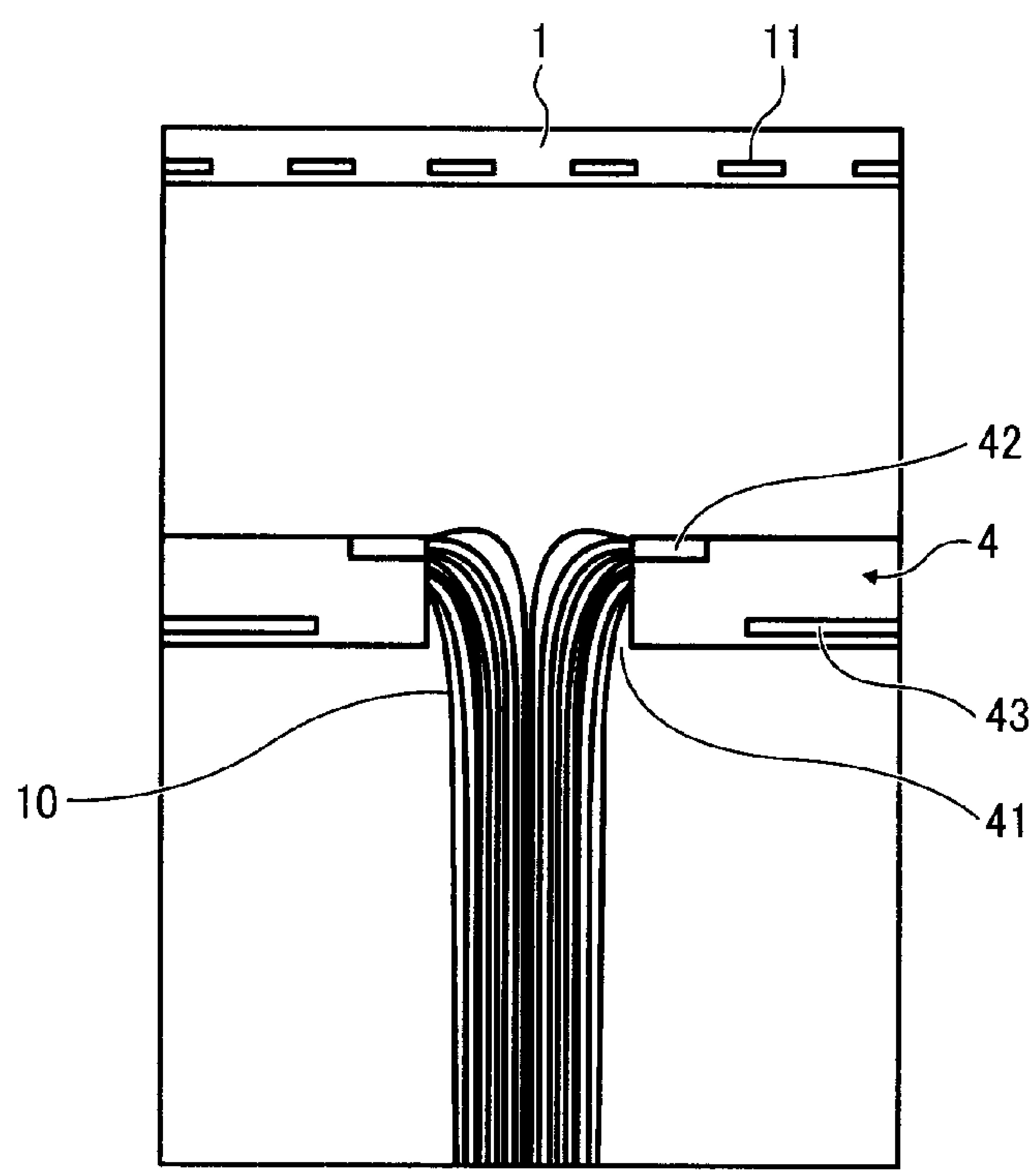

FIG. 5

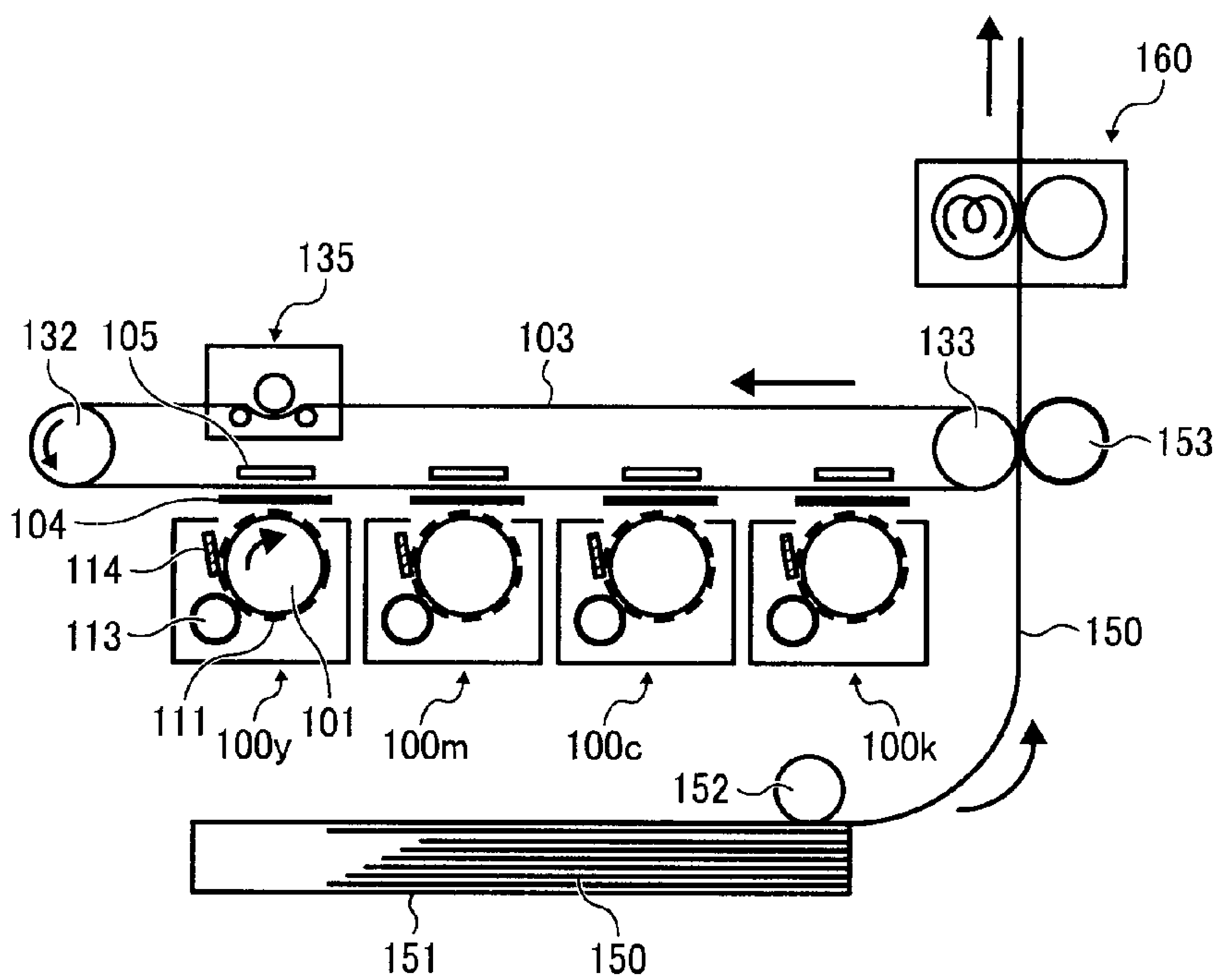
160
135
132 105
103
133
153
104
114
113
150
111
100y
101
100m
100c
100k
152
151
150

FIG. 6

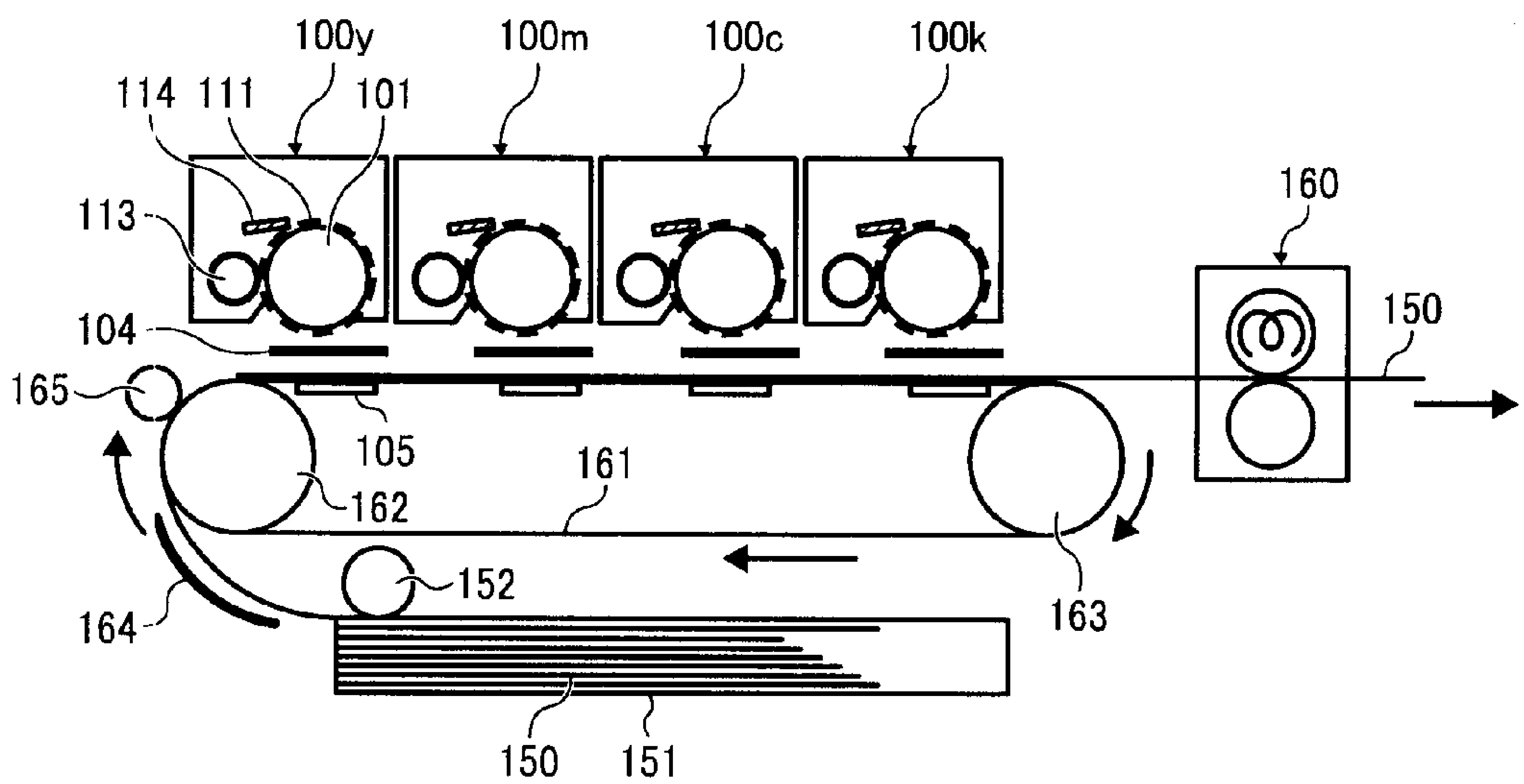
100y
100m
100c
100k
114 111
101
113
160
150
104
165
105
161
162
152
164
163
150 151

FIG. 7A

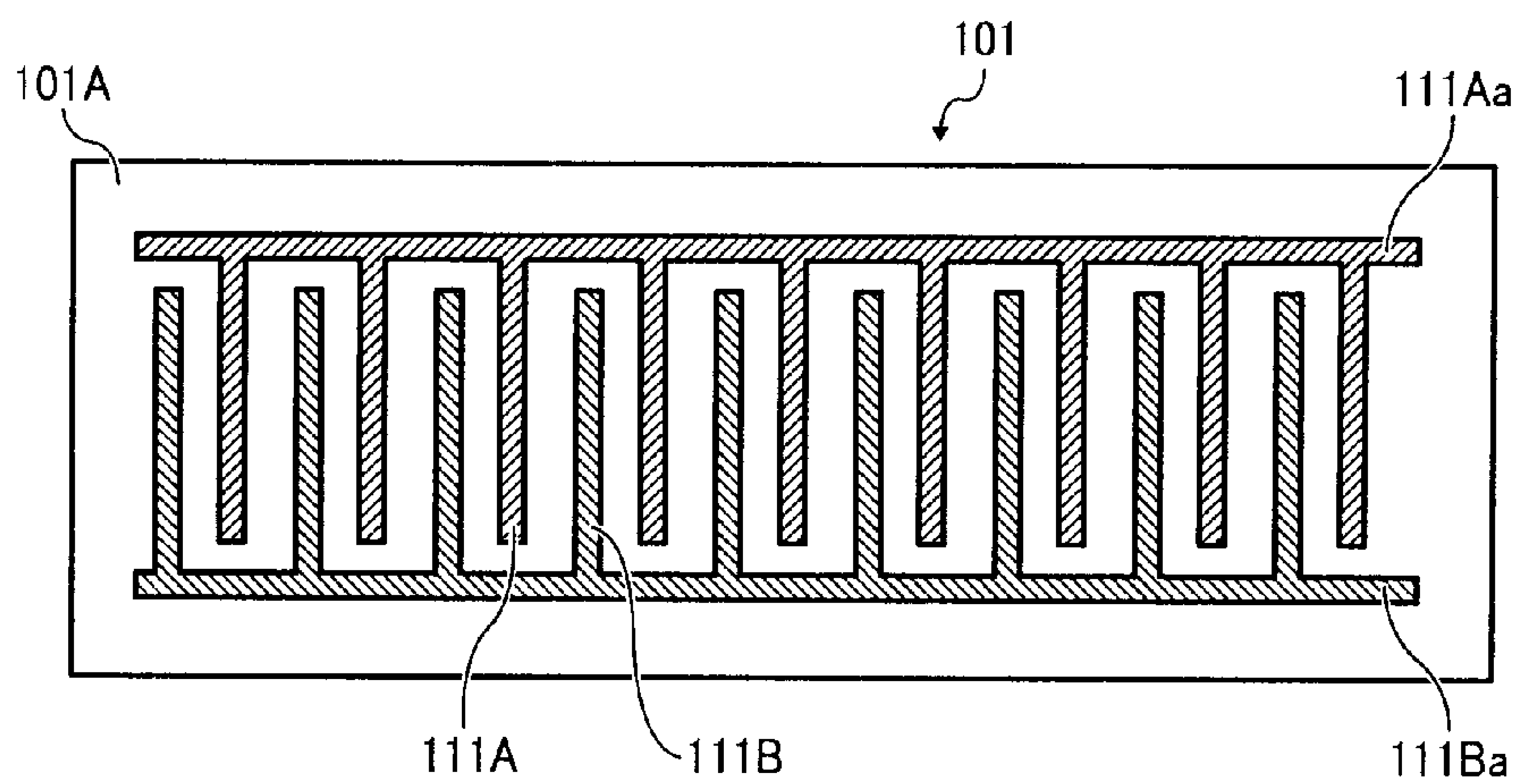

FIG. 7B

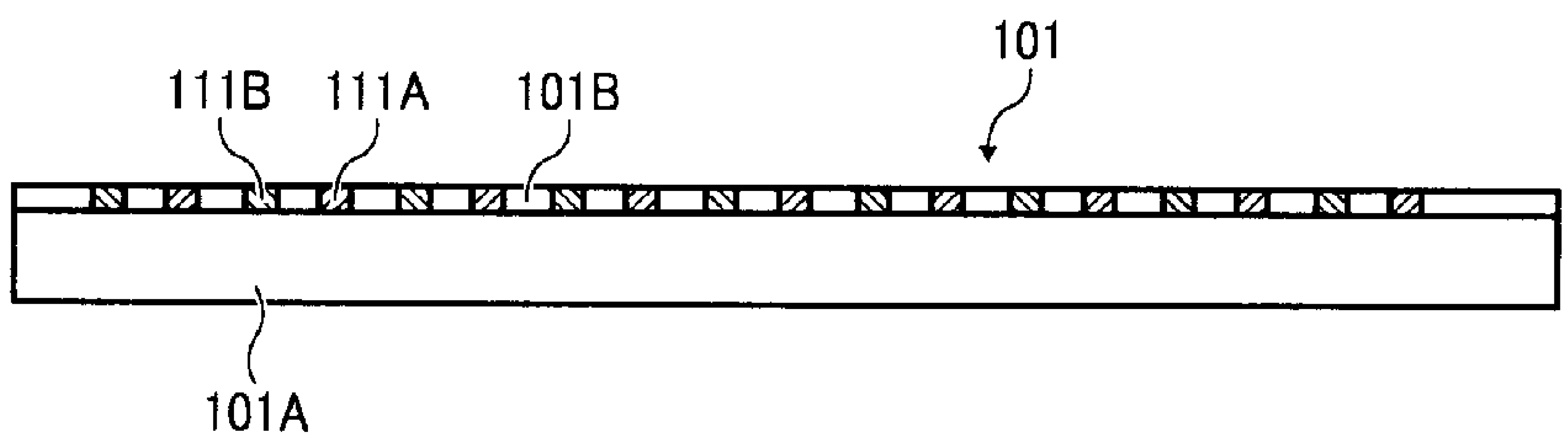

FIG. 8

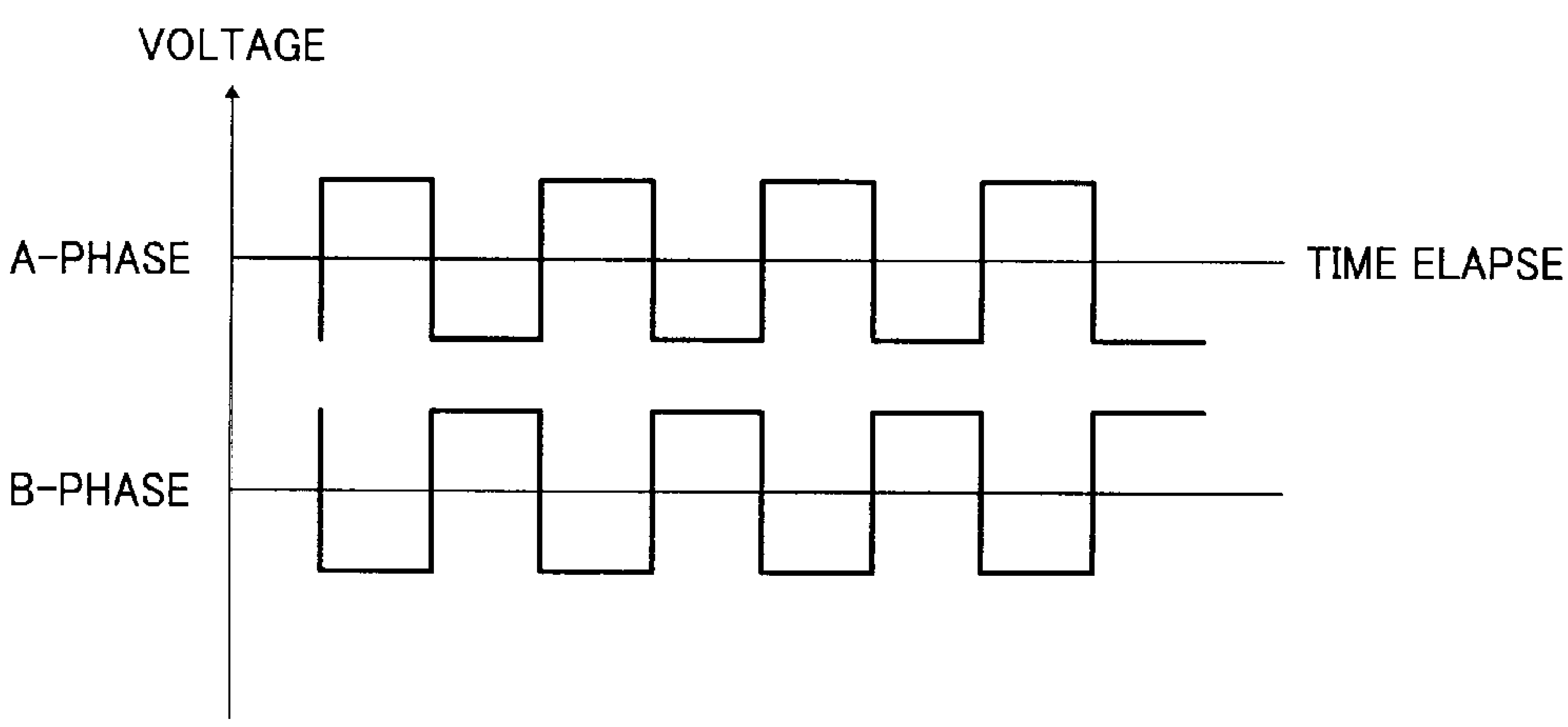

FIG. 9A

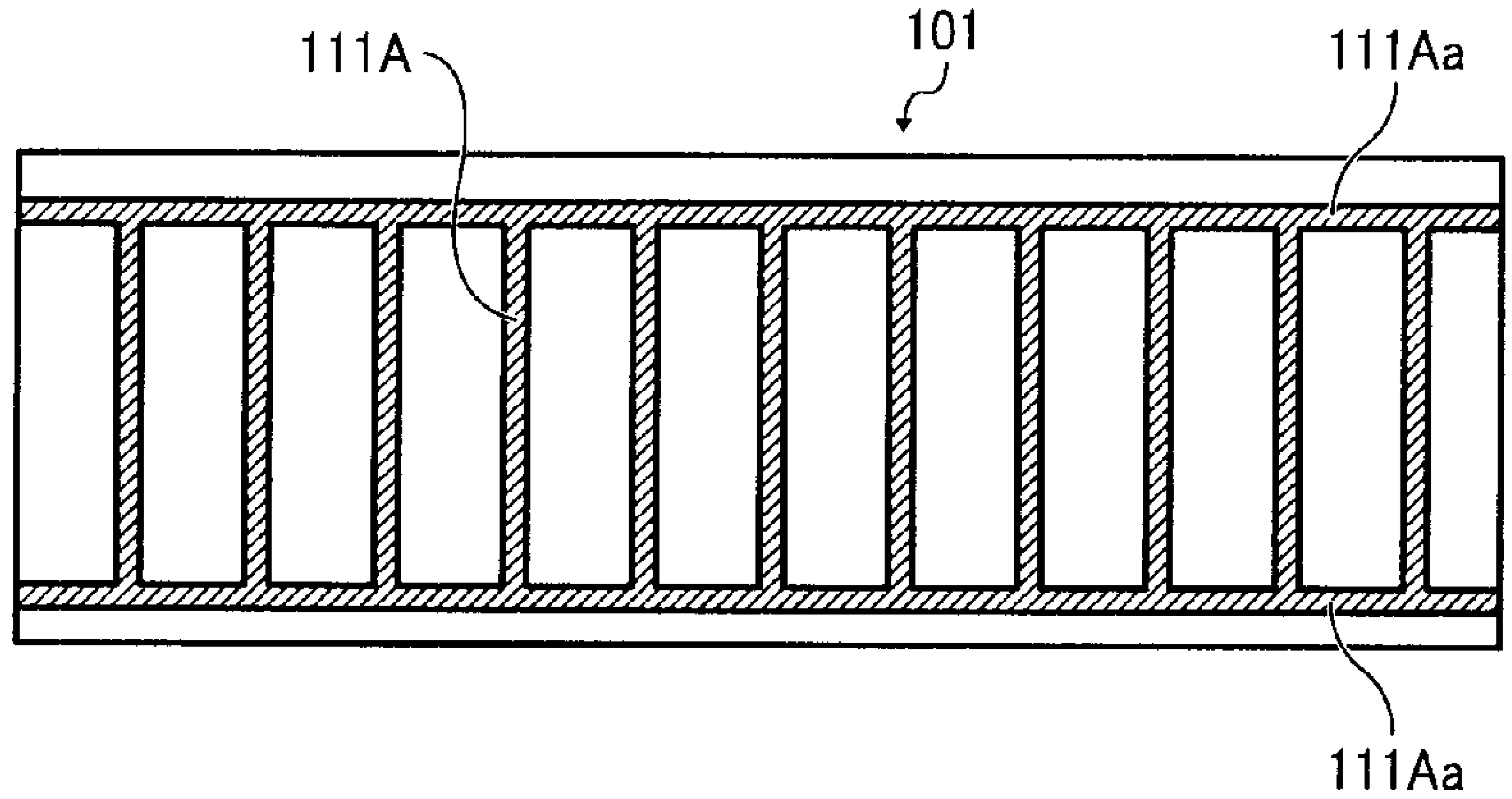

FIG. 9B

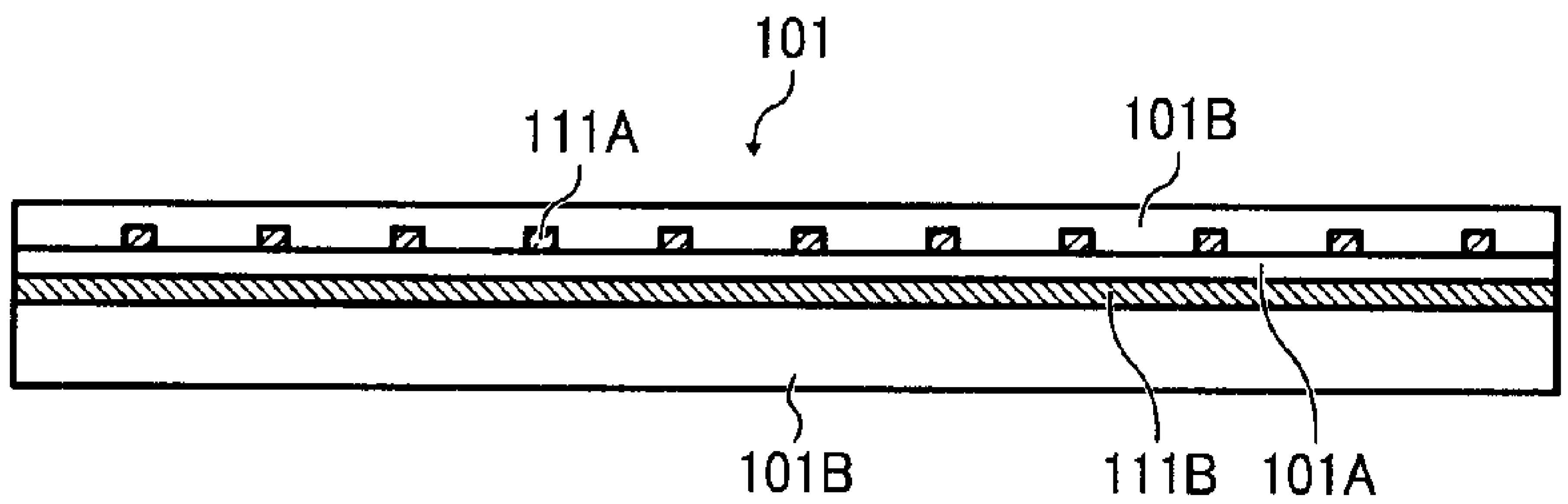

FIG. 10

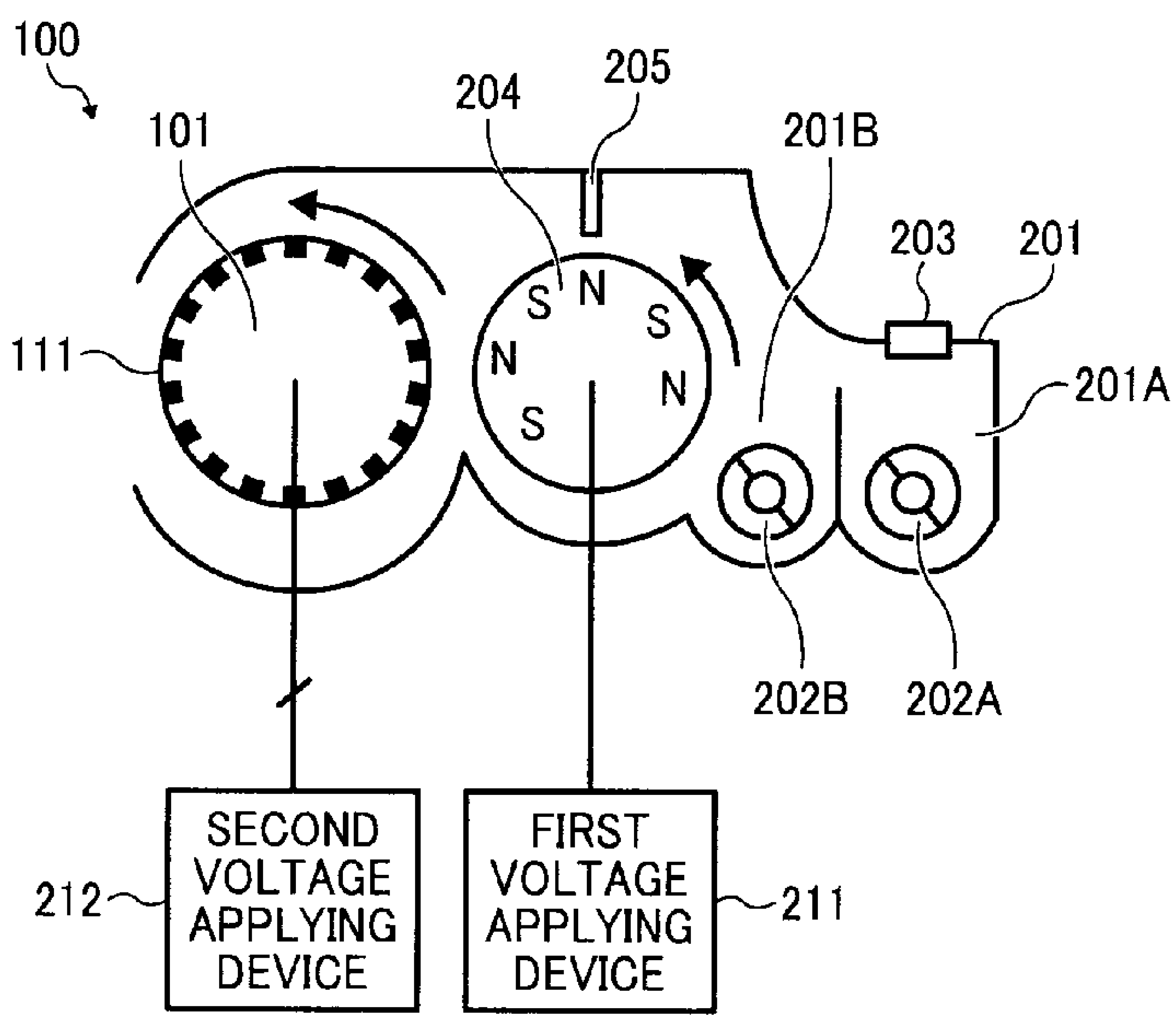

FIG. 11

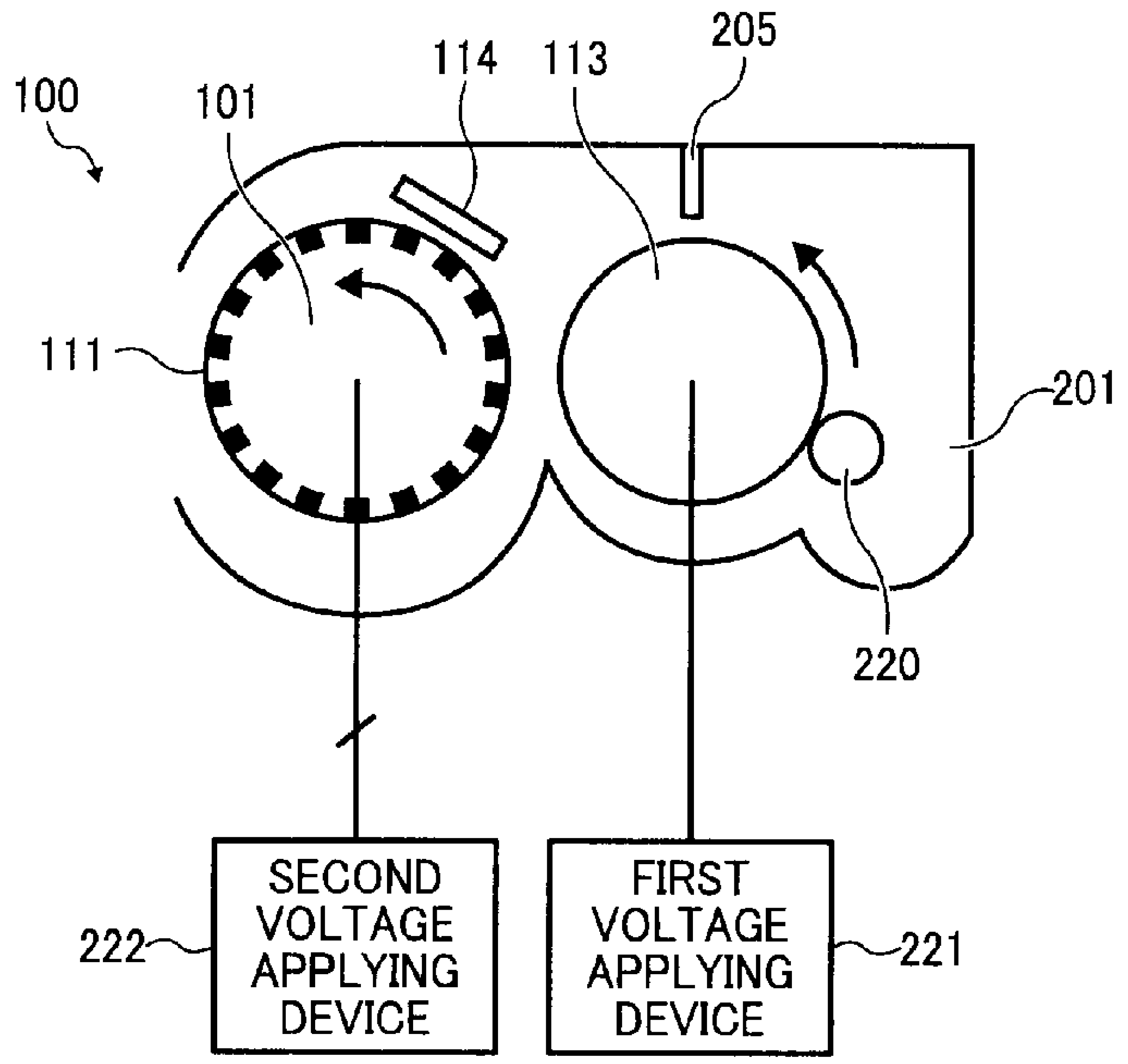

FIG. 12

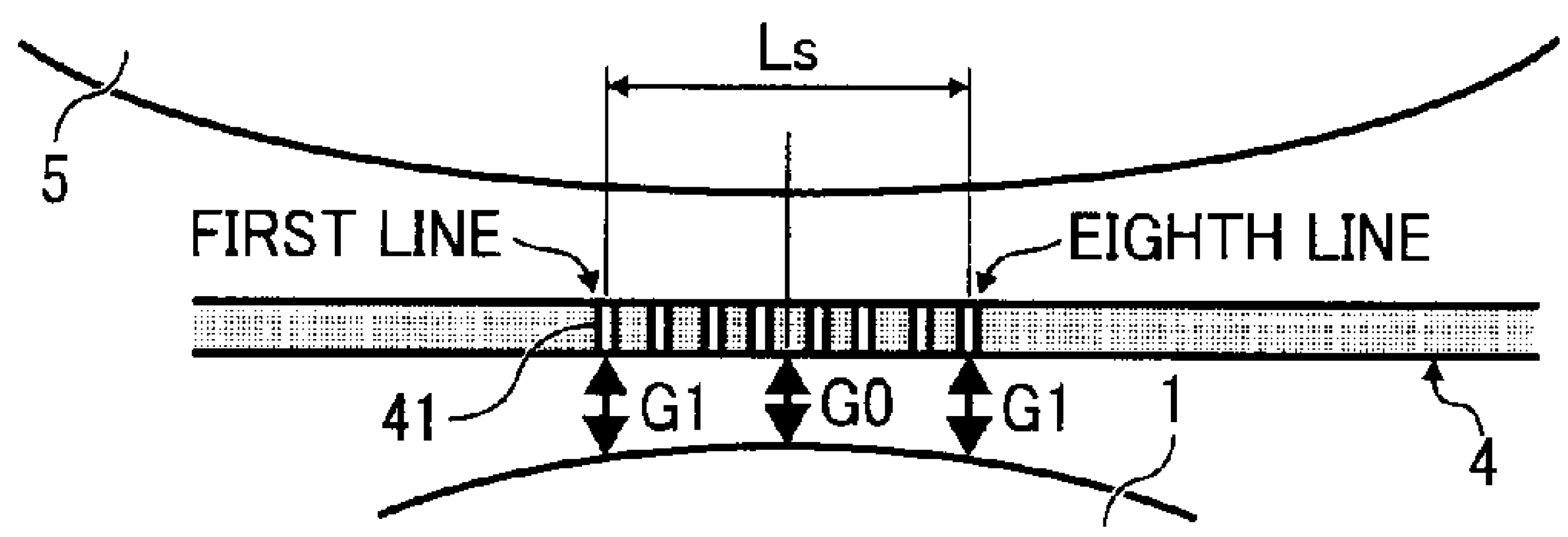

FIG. 13

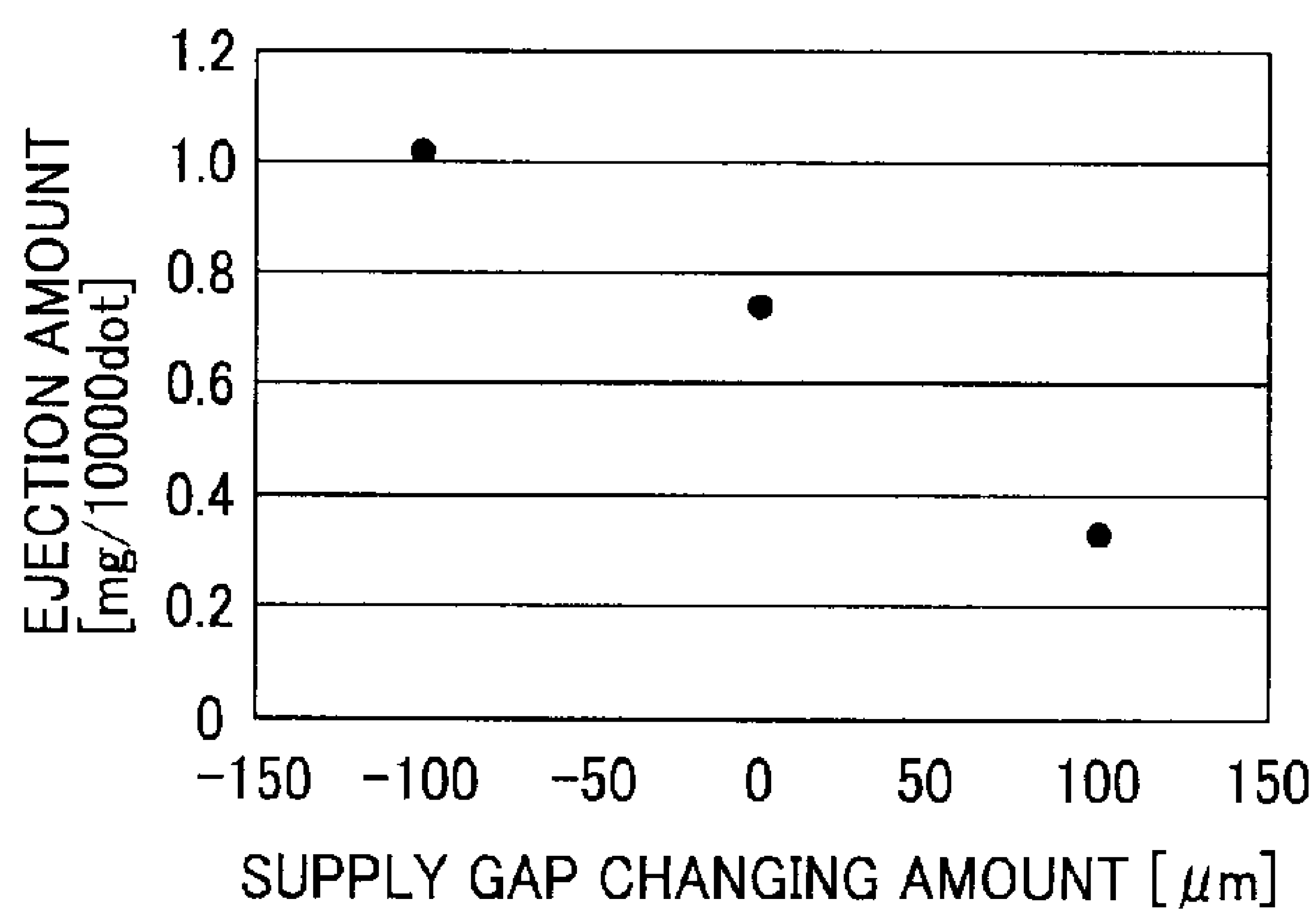

FIG. 14

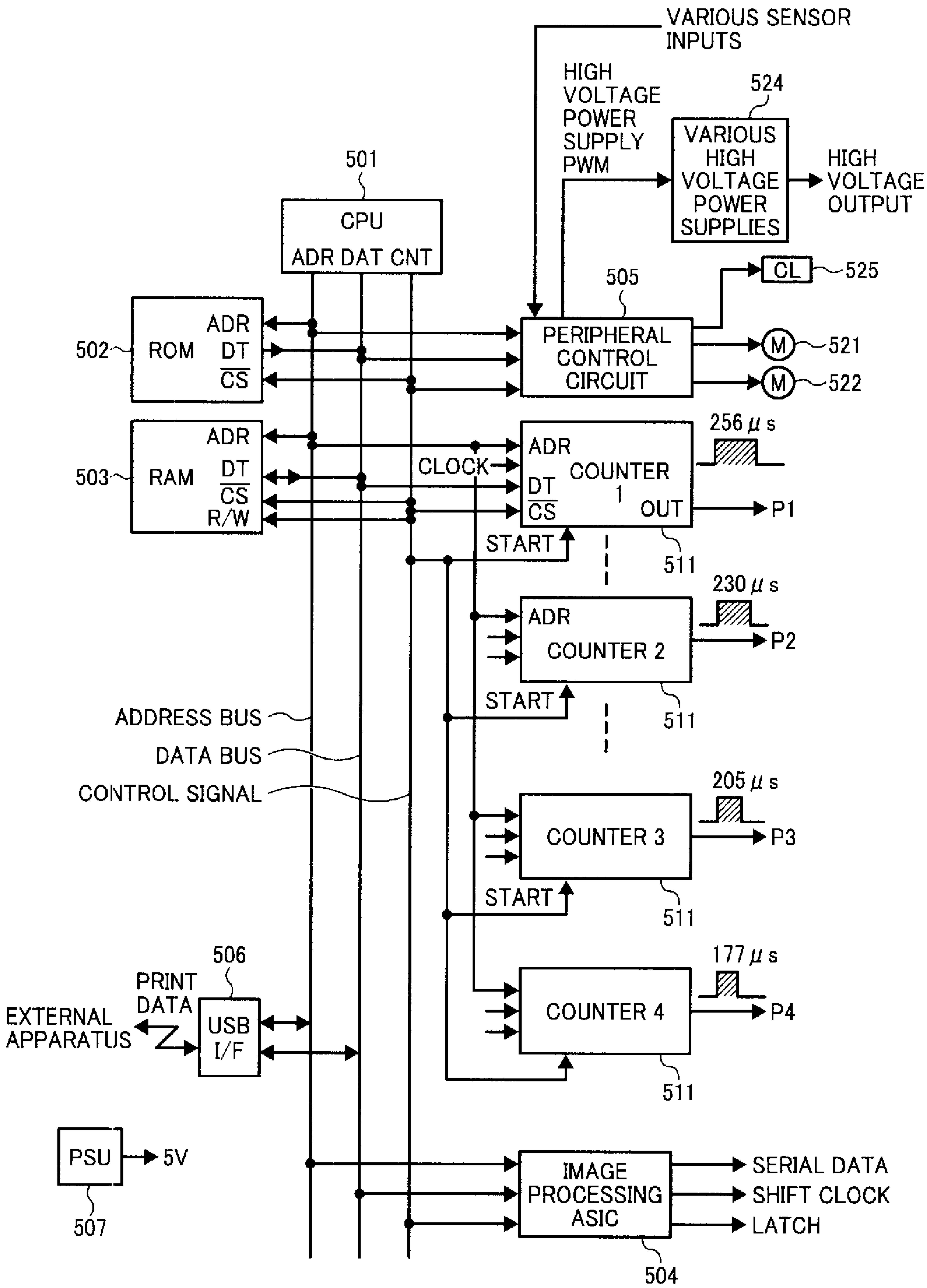
VARIOUS SENSOR INPUTS
HIGH VOLTAGE POWER SUPPLY PWM
524
VARIOUS HIGH VOLTAGE POWER SUPPLIES
HIGH VOLTAGE OUTPUT
501
CPU
ADR DAT CNT
CL
525
505
PERIPHERAL CONTROL CIRCUIT
521
522
502
ROM
ADR
DT
CS
503
RAM
ADR
DT
CS
R/W
CLOCK
ADR
DT
CS
COUNTER 1
OUT
256 μs
P1
START
511
230 μs
ADR
COUNTER 2
P2
START
511
ADDRESS BUS
DATA BUS
CONTROL SIGNAL
205 μs
COUNTER 3
P3
START
511
506
PRINT DATA
EXTERNAL APPARATUS
USB I/F
177 μs
COUNTER 4
P4
511
PSU
5V
507
IMAGE PROCESSING ASIC
SERIAL DATA
SHIFT CLOCK
LATCH
504

FIG. 15

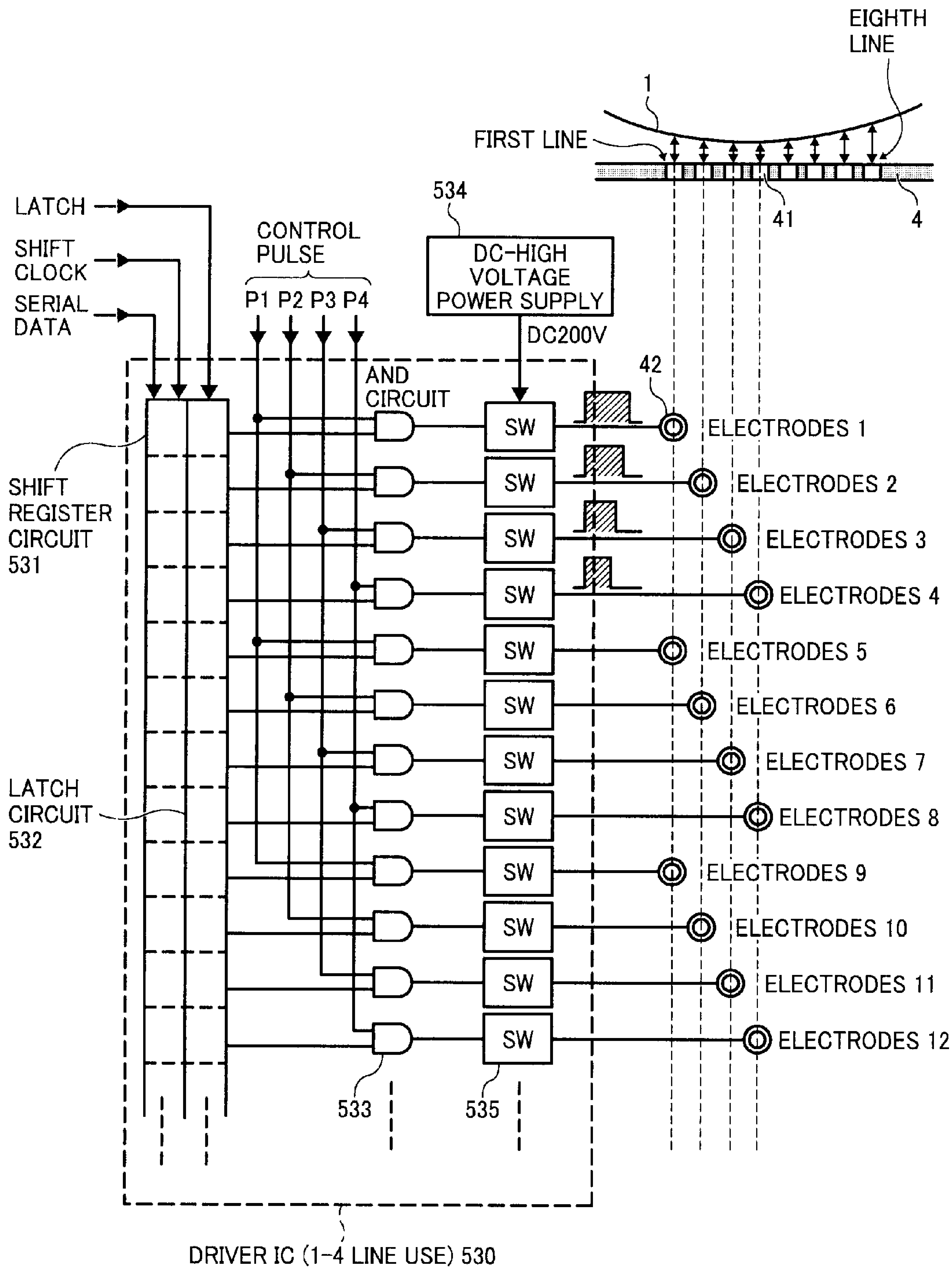
EIGHTH LINE
1
FIRST LINE
41
4
534
LATCH
SHIFT CLOCK
SERIAL DATA
CONTROL PULSE
P1 P2 P3 P4
DC-HIGH VOLTAGE POWER SUPPLY
DC200V
42
AND CIRCUIT
SW
ELECTRODES 1
ELECTRODES 2
ELECTRODES 3
ELECTRODES 4
ELECTRODES 5
ELECTRODES 6
ELECTRODES 7
ELECTRODES 8
ELECTRODES 9
ELECTRODES 10
ELECTRODES 11
ELECTRODES 12
SHIFT REGISTER CIRCUIT 531
LATCH CIRCUIT 532
533
535
DRIVER IC (1-4 LINE USE) 530

FIG. 16

PULSE WIDTH TABLE

LINE	PULSE WIDTH DATA
1	256
2	230
3	205
4	177
5	177
6	205
7	230
8	256

FIG. 17

PULSE WIDTH TABLE

	PULSE WIDTH DATA	
LINE	LINE SPEED 168mm/g	84mm/g
1	256 (69%)	492 (72%)
2	230 (77%)	448 (79%)
3	205 (86%)	402 (88%)
4	177 (1)	354 (1)
5	177	354
6	205	402
7	230	448
8	256	492

FIG. 18

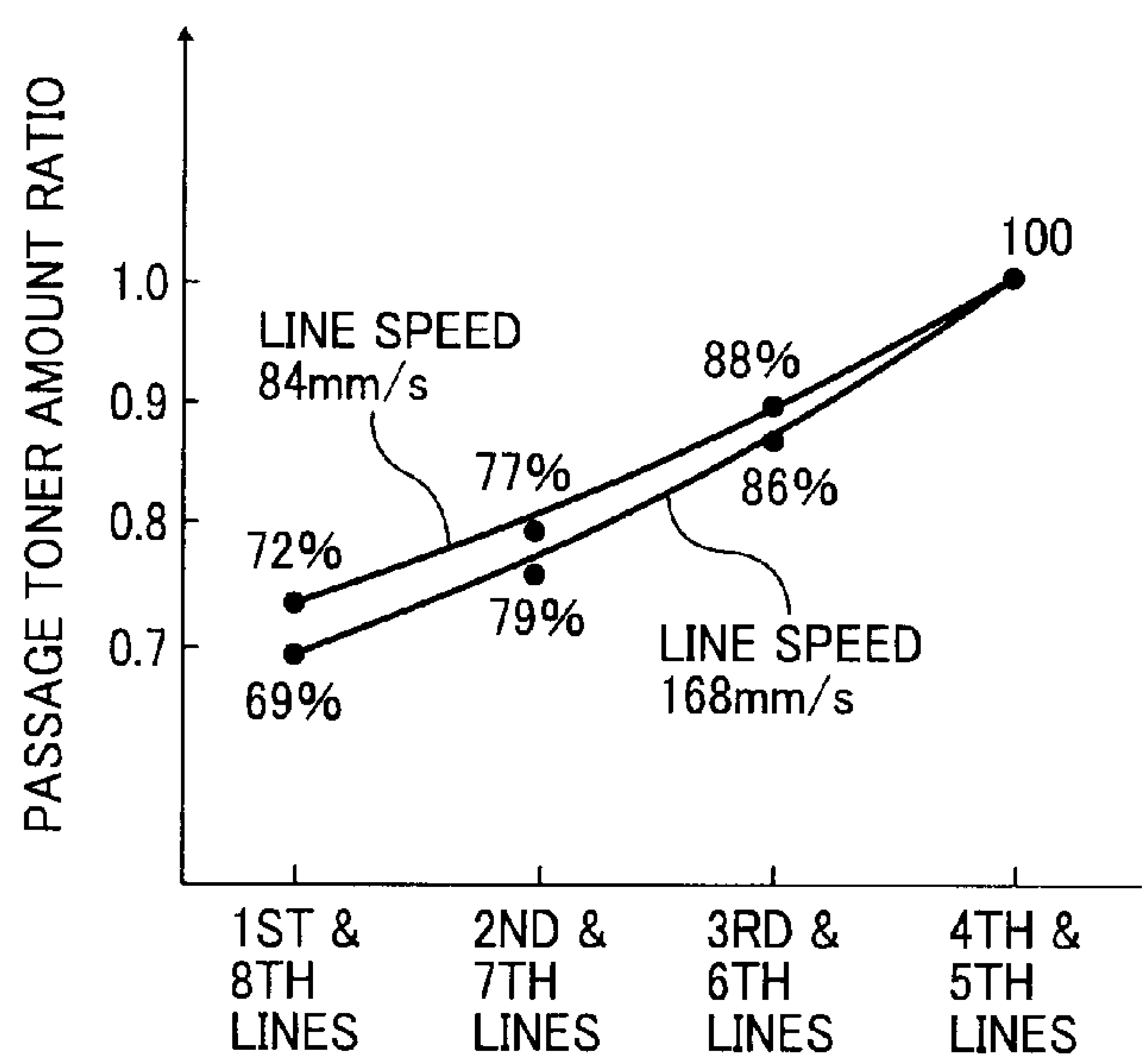

FIG. 19

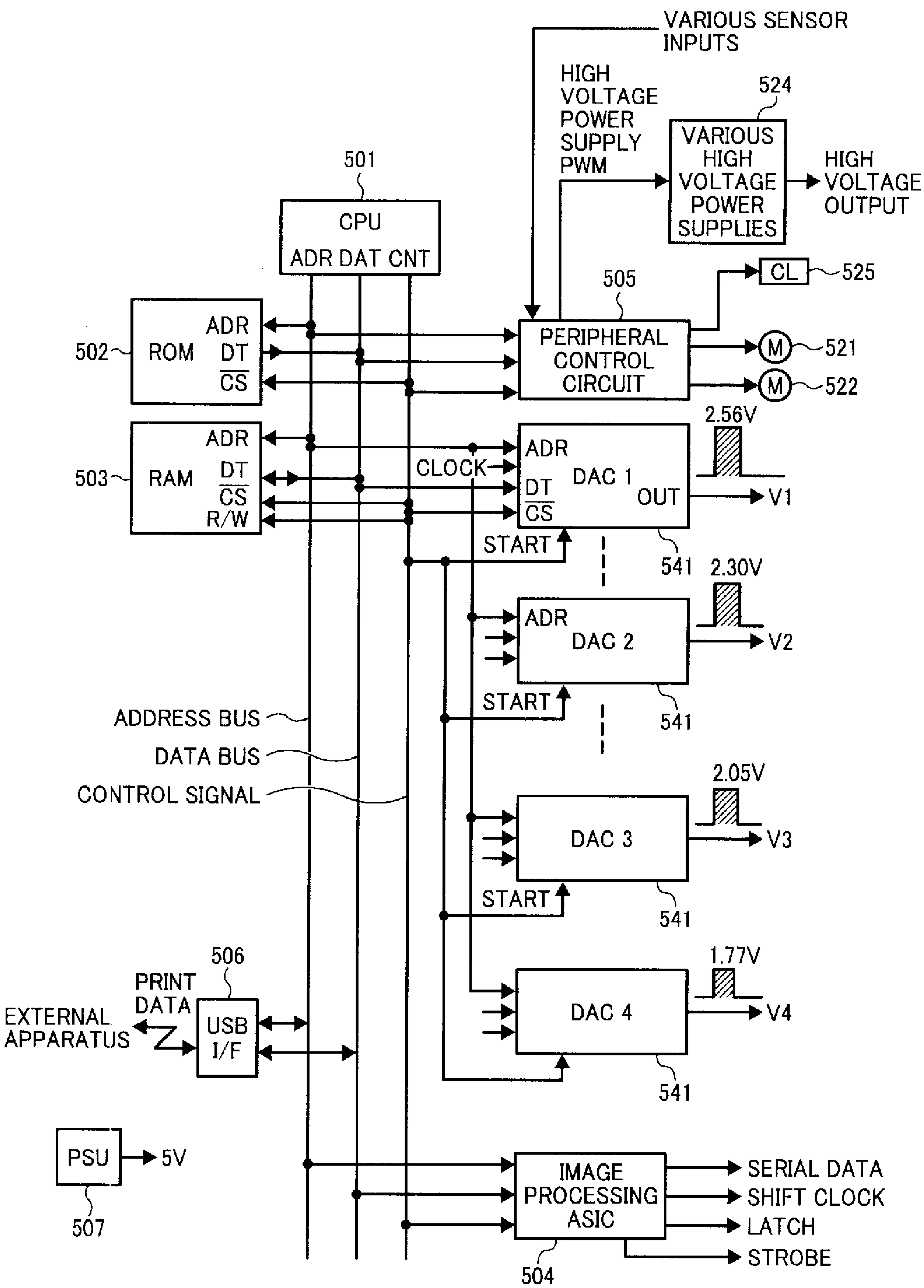
VARIOUS SENSOR INPUTS
HIGH VOLTAGE POWER SUPPLY PWM
524
VARIOUS HIGH VOLTAGE POWER SUPPLIES
HIGH VOLTAGE OUTPUT
501
CPU
ADR DAT CNT
505
CL
525
502
ROM
ADR
DT
CS
PERIPHERAL CONTROL CIRCUIT
M
521
522
503
RAM
ADR
DT
CS
R/W
CLOCK
DAC 1
OUT
2.56V
V1
START
541
2.30V
DAC 2
V2
ADDRESS BUS
DATA BUS
CONTROL SIGNAL
2.05V
DAC 3
V3
1.77V
DAC 4
V4
506
PRINT DATA
EXTERNAL APPARATUS
USB I/F
PSU
5V
507
IMAGE PROCESSING ASIC
504
SERIAL DATA
SHIFT CLOCK
LATCH
STROBE

FIG. 20

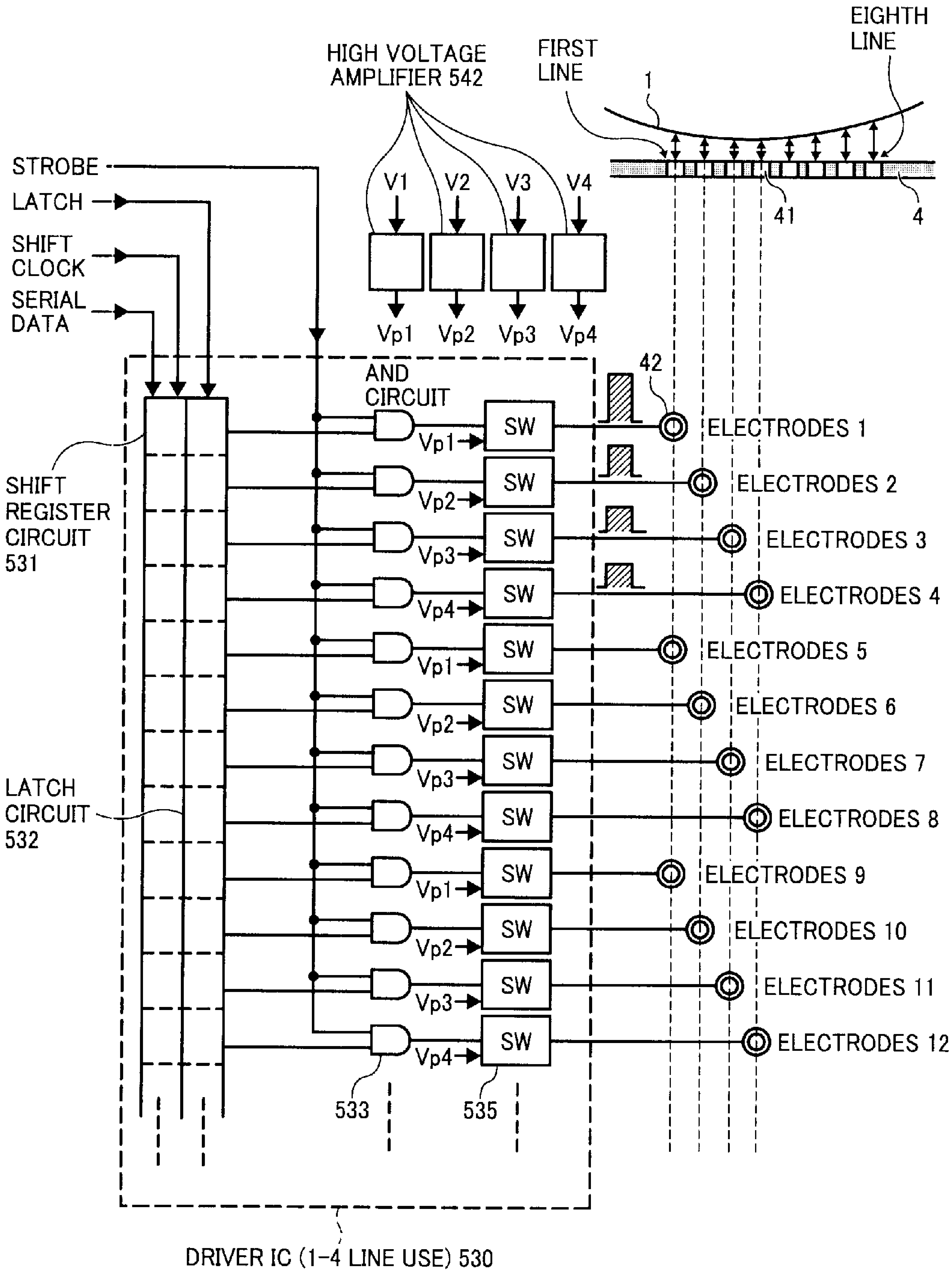
HIGH VOLTAGE AMPLIFIER 542
FIRST LINE
EIGHTH LINE
1
41
4
STROBE
LATCH
SHIFT CLOCK
SERIAL DATA
V1
V2
V3
V4
Vp1
Vp2
Vp3
Vp4
AND CIRCUIT
42
SW
SHIFT REGISTER CIRCUIT 531
LATCH CIRCUIT 532
ELECTRODES 1
ELECTRODES 2
ELECTRODES 3
ELECTRODES 4
ELECTRODES 5
ELECTRODES 6
ELECTRODES 7
ELECTRODES 8
ELECTRODES 9
ELECTRODES 10
ELECTRODES 11
ELECTRODES 12
533
535
DRIVER IC (1-4 LINE USE) 530

FIG. 21

WAVE HEIGHT VALUE TABLE

LINE	WAVE HEIGHT VALUE DATA
1	256
2	230
3	205
4	177
5	177
6	205
7	230
8	256

FIG. 22

	WAVE HEIGHT VALUE DATA	
LINE	LINE SPEED 168mm/s	84mm/s
1	256	492
2	230	448
3	205	402
4	177	354
5	177	354
6	205	402
7	230	448
8	256	492

FIG. 23

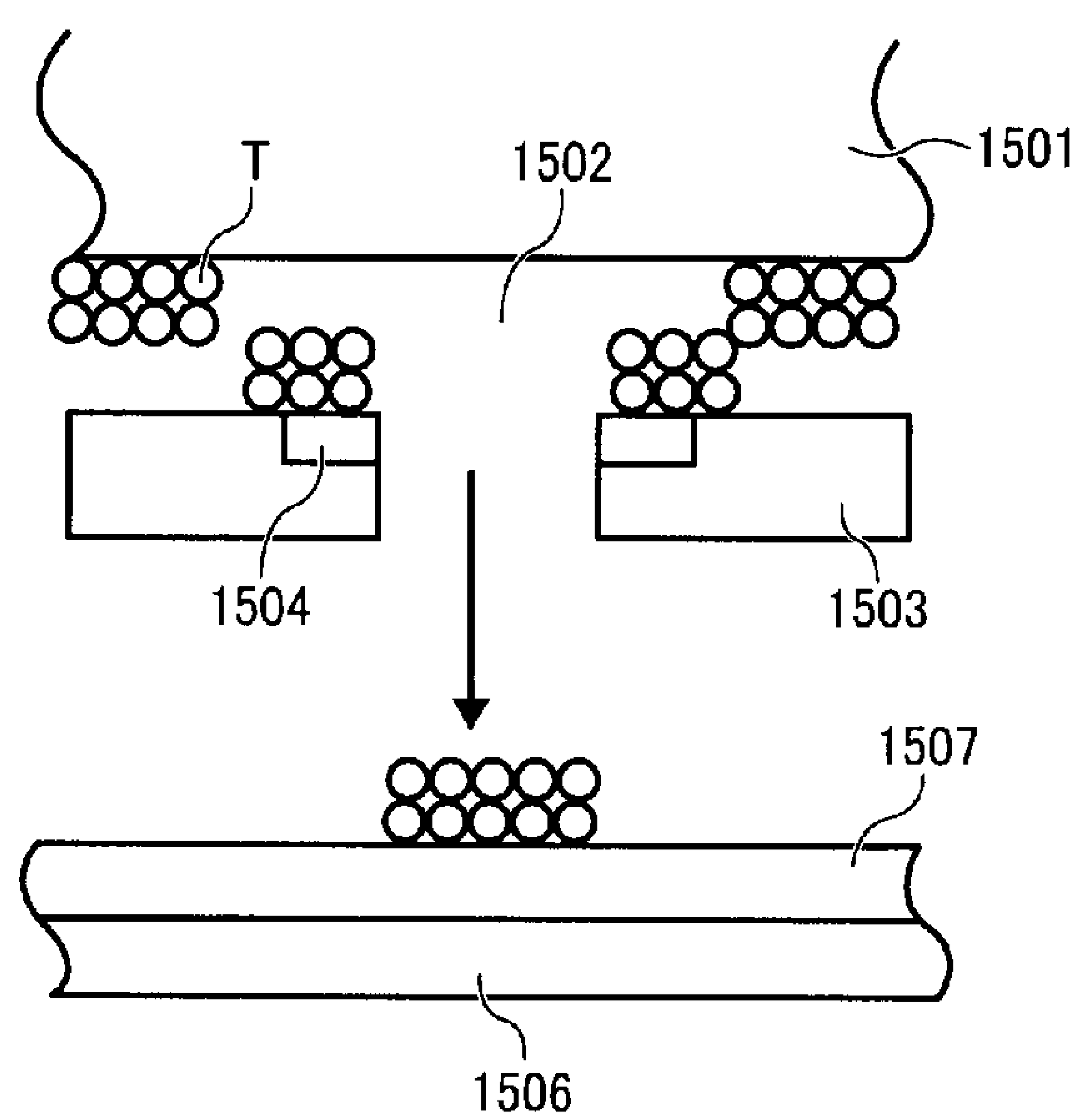

IMAGE FORMING APPARATUS WITH DEVELOPER PASSAGE AMOUNT CONTROL ELECTRODES

CROSS REFERENCE TO RELATED APPLICATION

This application claims priority under 35 USC §119 to Japanese Patent Application No. 2009-42846, filed on Feb. 25, 2009, the entire contents of which are herein incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an image forming apparatus, in particular, to that capable of forming an image on a printing medium by causing toner to soar and adhere to the printing medium from a toner bearing member via toner passage holes which are controlled to be open and close.

2. Discussion of the Background Art

As a conventional image forming apparatus, a toner jet, direct toning, and toner projection system or the like of that directly prints an image on a printing medium or an inter mediate transfer medium with toner is well known.

For example, the Japanese Patent Application Laid Open No. 63-136058 discloses a technology in that electric charge generated by friction caused between a fixed blade and a rotation roller is provided to toner, which is supplied from a toner hopper. The toner is then rotationally conveyed and is controlled to soar by a control pulse applied to a control member in an electric field that is created by the rotation roller.

The toner with electric charge electro-statically adheres to the surface of the rotation roller, and thus, needs to be separated by the control pulse. Since there exists a gap of more than 100 micrometer between the rotation roller and the control member, the control pulse necessarily needs a high voltage of more than 500V to execute the separation. Thus, a driver for control use needed corresponding to a number of pixels becomes extraordinary costly. Further, a responsibility becomes deteriorated and delayed due to necessity of separating and causing the toner to soar from the rotation roller.

The Japanese Patent Registration No. 2,933,930 and the Japanese Patent Publication No. 2-52, 260 disclose a technology in that a control pulse is inputted to a control electrode where developer passes while applying an alternating bias between a rotation developer bearing member and a control device.

With this system, the above-mentioned responsibility problem is decreased. However, since an alternating electric field is uniformly entirely provided to a toner soaring region, the developer repeatedly adheres and soars from and to the developer bearing member. Thus, the alternating bias need be intensive to separate the developer adhering to the developer bearing member. Thus, a lot of separated toner swiftly soars to the control device and unavoidably adheres to the electrode of the control device, and thereby reliability decreases. Further, the high voltage of more than 500V need be applied between the developer bearing member and the control device, because a gap exists therebetween. Thus, the control pulse that causes the electric field either to allow or prohibit passage of toner in the electric field similarly needs a high voltage. Thus, the driver cost problem is yet unsolved.

The Japanese Patent Application Laid Open No. 59-181370 discloses that a developer bearing member includes plural electrodes and creates electric fields that

change between the plural electrodes as time elapses, so that toner soars toward a control electrode.

Since the toner soaring and floating in the vicinity of the control electrode is controlled, the problem of increase of the control voltage existing in the above-mentioned Japanese Patent Application Laid Open No. 63-136058, the Japanese Patent Registration No. 2933930, and the Japanese Patent Publication No. 2-52260 is resolved.

As in the Japanese Patent Application Laid Open No. 59-181370, the Japanese Patent Application Laid Open No. 02-226261 discloses a technology in that a developer bearing member includes plural electrodes and creates electric fields that change as time elapses between these plural electrodes, so that toner soars. However, a control electrode that controls passage of the toner conventionally arranged on the printing medium side is arranged on a toner supplying surface side.

In this system, the control voltage can be decreased from the conventional 400V down to 100V. Further, when toner adhering to a printing head where the control electrodes are arranged is removed, the toner can be collected in a toner supply source.

For example, as shown in FIG. **23**, a conventional direct printing system includes a toner bearing roller **1501** arranged as an agent bearer with its axis being extended left and right in the drawing and bears toner T having been charged thereon while driven rotated by a drive device, not shown. Below the toner bearing roller **1501**, a flexible print baseboard (FPC) **1503** is arranged as a hole formation member having plural holes **1502**. The FPC **1503** includes plural ring state soar electrodes **1504** surrounding the plural holes **1502** respectively while opposing the toner bearing roller **1501**.

Below the FPC **1503**, an opposing electrode **1506** is arranged opposing the toner bearing roller **1501**. Also arranged is a printing sheet **507** conveyed above the opposing electrode **1506** by a conveyance device. Even only one hole **1502** and such a soar electrode **1504** are illustrated there, these plural combinations are practically formed on the FPC **1503**. Specifically, a FPC **1503** for 600 dpi use includes 4960 items of these combinations.

The toner bearing roller **1501** is grounded, for example, and bears toner T charged in a negative polarity. When a soar voltage of the positive polarity is applied to the soar electrode **1504**, the toner T on the toner bearing roller **1501** opposing the soar electrode **1504** or that in the vicinity thereof are subjected to an electric field having a prescribed intensity. Due to influence of the electric field, an electrostatic force applied to the toner T exceeds an attraction force attracting the toner T to the toner bearing roller **1501**. Thus, aggregation of toner T selectively soars and enters the hole **1502** in a dot state from the loner bearing roller **1501**.

Then, the toner T is drawn by an electric field created between the soar electrode **1504** and the above-mentioned intensively charged opposing electrode **1506** and keeps soaring and attracts the toner to the surface of the printing sheet **1507** via the hole **1502**, so that the aggregation of the toner T becomes a dot image.

In such a situation, a soar voltage applied to each of the soar electrodes **1504** needs to be controlled to turn on and off independently by a different private use IC. Specifically, when the voltage is high, the image forming apparatus of the direct printing system needs the same number of expensive ICs as the soar electrodes **1504**. For example, the FPC **3** for 600 dpi use is employed, 4960 items of expensive switching elements are needed. In general, as voltage endurance increases, an IC becomes expensive due to increase of a chip area. Thus, it is significant for the image forming apparatus of the direct printing system to decrease the control voltage in view of cost.

However, an attraction force attracting each other is created between the toner T and the toner bearing roller **1501** by a mirror image force, a van der Waals force, a liquid cross-link force or the like, and makes the soar voltage difficult to decrease. As a result, the soar voltage of more than 500 v needs to be applied in the above-mentioned apparatus.

However, the voltage applied to the soar electrode can be decreased if the developer bearer includes plural electrodes and a timely changing electric field is created between these electrodes so that toner is made in a cloud state and soars toward the control electrode as described in the Japanese Patent Application Laid Open No. 59-181370.

However, since the toner bearing roller bears the toner with charge on its surface while being driven rotated by a drive device, it necessarily has a prescribed curvature on its surface. Since the control electrode is substantially planer, a space distance between the toner bearing roller and the control electrode is different per line of the electrodes. Owing to this, it is revealed that an amount of the toner passing through a hole on a line of the electrode far distanced from the toner bearing roller is less than that of the other line distanced closer. Further, such tendency becomes prominent in a low voltage applied region. In any event, an amount of toner passing through a toner passage hole need to be highly precisely controlled to achieve high speed and high quality image formation.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above noted and another problems and one object of the present invention is to provide a new and noble image forming apparatus. Such an image forming apparatus comprises a toner-bearing member that bears toner and makes the toner clouded thereon. A toner passage control device including plural widthwise lines of toner passage holes in a printing medium electrode direction is provided. Each of the toner passage holes includes a control electrode that controls passage of the toner through each of the toner passage holes toward a printing medium. a control pulse proving device provides a control pulse to the control electrode to operate. The control pulse applied to the control electrode of the one of the plural lines is different from that applied to the control electrode of the other one of the plural lines.

In another aspect, the control pulse is different from the other by including at least one of a different pulse width and a different pulse wave height.

In yet another aspect, the control pulse corresponds to a printing line speed.

In yet another aspect, the printing medium includes a printing sheet. A sheet opposing electrode is arranged on a backside of the printing sheet to receive a bias directing toward the printing sheet.

In yet another aspect, the printing medium includes an intermediate transfer medium. A medium opposing electrode is arranged on a backside of the intermediate transfer medium to receive a bias directing toward the intermediate transfer medium.

In yet another aspect, a color image formation device is provided to form a color image on the printing medium.

BRIEF DESCRIPTION OF DRAWINGS

A more complete appreciation of the present invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. **1** typically illustrates an exemplary configuration according to one embodiment of the present invention;

FIG. **2** illustrates an exemplary control pulse applied to a control electrode;

FIG. **3**A illustrates a printing surface side of an exemplary toner control device;

FIG. **3**B illustrates a toner supply surface side of the exemplary toner control device;

FIG. **4**A illustrates an exemplary electric force line passing through a toner passage hole obtained based on a simulation result of a two dimensional cross sectional electric field intensity distribution when the toner control device is in a toner passage possible condition;

FIG. **4**B illustrates an exemplary electric force line passing through a toner passage hole obtained based on a simulation result of a two dimensional cross sectional electric field intensity distribution when the toner control device is in a toner passage impossible condition;

FIG. **5** typically illustrates an exemplary image forming apparatus according to one embodiment of the present invention;

FIG. **6** typically illustrates another exemplary image forming apparatus according to one embodiment of the present invention;

FIG. **7**A is an exploded view typically illustrating the exemplary toner bearing member;

FIG. **7**B is a cross sectional view typically illustrating the exemplary toner bearing member;

FIG. **8** illustrates exemplary pulse voltages applied to electrodes included in the toner bearing member;

FIG. **9**A is an exploded plan view typically illustrating another exemplary toner bearing member;

FIG. **9**B is a cross sectional view typically illustrating the other exemplary toner bearing member;

FIG. **10** illustrates an exemplary toner supply unit according to another embodiment of the present invention;

FIG. **11** illustrates another exemplary toner supply unit according to yet another embodiment of the present invention;

FIG. **12** illustrates an exemplary variation in a space distance between a control electrode included in a toner control member and the toner bearing member;

FIG. **13** illustrates an exemplary relation between the variation of the space distance and a toner-ejecting amount (i.e. passage amount);

FIG. **14** is a block chart illustrating an exemplary configuration of a control section according to a first example of the present invention;

FIG. **15** is a block chart illustrating an exemplary configuration of a driver IC section included in the control section of the present invention;

FIG. **16** illustrates an exemplary pulse width data table according to yet another embodiment of the present invention;

FIG. **17** illustrates another exemplary pulse width data table according to one embodiment of the present invention;

FIG. **18** illustrates an exemplary relation between a printing line speed, an amount of passage toner, and a line position of toner passage holes;

FIG. **19** is a block chart illustrating another exemplary configuration of the control section according to a second example of the present invention;

FIG. **20** is a block chart illustrating an exemplary configuration of a driver IC section included in the control section according to the second example of the present invention;

FIG. **21** is a chart illustrating an exemplary wave height data table;

FIG. **22** is a chart illustrating another exemplary wave height data table; and

FIG. **23** typically illustrates a fundamental configuration of an apparatus employing a conventional direct printing system.

PREFERRED EMBODIMENTS OF THE PRESENT INVENTION

Referring now to the drawings, wherein like reference numerals and marks designate identical or corresponding parts throughout several figures, in particular in FIG. **1**, an image forming apparatus is described. As shown, a first embodiment of the image forming apparatus includes a roller state toner bearing member **1** that bears and causes toner T to soar, a printing medium **3** to which the toner T is adhered, and a toner control device **4**, having plural toner passage holes **41**, arranged between the toner bearing member **1** and the printing medium **3**.

The toner bearing member **1** includes plural electrodes **11** on its surface extending in an axial direction perpendicular to a direction in which toner T is conveyed with a prescribed pitch. A pulse voltage application device (e.g. power supply) **6** applies a timely changing pulse voltage (i.e. a cloud pulse) to each of the electrodes **11** on the toner bearing member **1**.

For example, a pulse voltage Vs is applied at a frequency from 0.5 to 7 kHz. Since an interval of the respective electrodes **11** is finely formed, an intensive electric field is created therebetween. Thus, the toner T vigorously soars from an electric field having a prescribed voltage that repels the toner T of a charge polarity and is pulled by an electrode **11** having a prescribed voltage attracting the toner T. The toner repeats such up and down soaring in accordance with a pulse frequency in response to switching of the pulse voltage Vs and becomes a cloud state.

The toner control device **4** includes plural lines of toner passage holes (e.g. openings) **41**, which the toner T can pass through, as typically shown in FIG. **1**. In the periphery of the toner passage hole **41** on the toner supply side surface of the toner control device **4**, a ring state control electrode **42** is arranged. A common electrode **43** is further arranged on the printing surface side beside the toner passage hole **41**.

To the control electrode **42**, a control pulse Vc is applied from a drive circuit **7** constituting a control pulse application device as shown in FIG. **2**. In this situation, when the toner passage hole **41** is brought into a condition allowing the toner T to pass (i.e., ON condition), a voltage Vc-on is applied to the control electrode **42**. Whereas when the toner passage hole **41** is brought into a condition prohibiting the toner T to pass (i.e., OFF condition), a voltage Vc-off is applied to the control electrode **42**. Further, a voltage Vrg is always applied from a power supply **8** to the common electrode **43** to prevent mutual interference due to crosstalk of neighboring electric fields on a print surface side region.

The control electrode **42** can sufficiently operate even only arranged in the periphery of the passage hole **41**. However, the control electrode **42** can be arranged either only on an inner wall surface of the passage hole **41** or both on the same and in the periphery of the toner bearing member side.

To the backside surface of the printing medium side, a bias voltage Vp is applied to attract toner T having passed through the toner control device **4** to the printing medium **3**. Specifically, a backside electrode **5** is arranged as an opposing electrode device serving as a bias voltage application device. To attract the toner T having passed through the toner control device **4** to the printing medium **3**, a bias voltage Vp is applied from the bias power supply device **9**.

The printing medium **3** can be an intermediate transfer-printing medium capable of temporarily forming an image thereon and transferring the same onto a sheet or a printing sheet. To apply the bias voltage Vp to the printing medium **3**, a backside electrode **5** can be arranged on a backside of the printing medium **3** (e.g. an opposite side surface of the toner bearing member **1**), while the printing medium **3** is conveyed on the backside electrode **5**. When the intermediate transfer-printing medium is used, an electrode can be embedded therein (e.g. an opposing electrode device on the printing medium side serves as an inner electrode) or the backside electrode **5** can be arranged on the backside thereof.

As a cloud making device that makes cloud toner on the surface of the toner-bearing member **1**, plural electrodes **11** are alternately arranged on the surface of the toner-bearing member **1** in the rotational direction to receive a voltage Vs. Specifically, these electrodes **11** form a two-phase and are arranged with a pitch p, to which a voltage capable of attracting and repelling toner T between the neighboring electrodes **11** is applied. Otherwise, two-phase voltages are applied to neighboring electrodes **11**.

Now, an exemplary toner control device **4** is described with reference to FIGS. **3**A and **3**B. As shown, on the toner supply side of the insulation substrate **45**, a ring state control electrode **42** having a width of from 10 to 100 micrometer is arranged surrounding the toner passage hole **41**.

A diameter of the toner passage hole **41** is determined based on a diameter of a dot to be formed, and is preferably from 50 to 200 micrometer. A lead pattern **42***a* connects the driver circuit **7** with the control electrode **42**, which controls passage of the toner T.

The print surface side includes a common electrode **43** on a section other than a periphery of the hole. The common electrode **43**, and receives a DC voltage not to be affected by neighboring electric fields even if voltages Vc-on and Vc-off are applied to the control electrode **42**. Specifically, in order to independently form an electric force line flux having a prescribed electric force between the toner supply side and the printing medium side per toner passage hole, it is attempted to suppress the mutual interference when toner soars from plural nozzle passage holes in a multi driving condition.

Such a toner control device **4** is produced in the following manner. Specifically, in views of cost and a manufacturing process, resin film, such as polyimide, PET, PEN, PES, etc., having a thickness of from 30 to 100 micrometer is employed as an insulation member of the substrate **45**. Initially, aluminum vapor deposition coats are formed on both sides of a film. As a photolithography process applied to the surface, a photo registration is coated having a thickness of from 0.2 to 1 micrometer using a spinner. Previous baking, mask exposure, and development are then executed. Then, photo registration is heated and hardened. Similarly, as a pattern of the printing medium surface side, the photolithography process is executed on the backside in the same manner as above. Then, aluminum patterning is executed using aluminum etching liquid.

To precisely form the toner passage hole **41** while avoiding positional deviation, a machine process by means of pressing is applied after pattern formation, an excimer laser process is applied to a pattern, or a dry etching process such as sputter etching process using a metal mask, etc., is applied.

In the image forming apparatus configured in this way, when two-phase pulse voltages having a different phase of 180 degree are applied to the electrodes **11**, toner T soars and is clouded on the toner bearing member **1** and is conveyed as the toner bearing member **1** rotates. To the backside electrode **5**, a print bias voltage Vp is applied.

In this situation, a voltage Vrg is applied to the common electrode **43** and a voltage Vc-on of an ON condition voltage as shown in FIG. **2** is applied to the control electrode **42** when the toner T is controlled to pass through the toner passage hole **41** (ON condition). Whereas a voltage Vc-off of an OFF condition voltage as shown in FIG. **2** is applied when the toner T is prohibited to pass through the toner passage hole **41** (OFF condition).

In such a situation, prescribed voltages to be applied to the respective electrodes **11**, **5**, **42**, and **43** as mentioned later are designated, an electric line flux **10** is formed from the side of the printing medium **3** to the toner supply side when the voltage Vc-on is applied.

Thus, the toner in the cloud state on the toner bearing member **1** reaches the printing medium **3** passing through the toner passage hole **41** riding on the electric field of the electric line flux **10**. Accordingly, by controlling opening (turning on and off) of the toner control device **4** in accordance with presence of an image, a toner image can be directly formed on the printing medium **3**.

Now, a pulse voltage Vs to be applied to an electrode **11**, a bias voltage Vp applied to a printing medium side, and a control pulse voltage Vc to be applied to a control electrode **42** are described more in detail with reference to FIG. **4**.

As shown, a pulse voltage (e.g. a timely changing voltage) Vs is applied to the electrode **11**. A wave height of the bias voltage is designated in accordance with the pitch or usage toner. According to an experiment, it was revealed that toner can soar when the voltages are designated within from ±60 to ±300 Vpp (pp: peak to peak). In this simulation, ±200 Vpp with a DC zero volt component is applied. A gap d between the toner bearing member **1** and the toner control device **4** is 0.2 mm.

Further, the diameter of the toner passage hole **41** is 120 micrometer, a width of the ring state control electrode **42** in a hole center direction is 50 micrometer, and an interval between the common electrode **43** and the hole is 50 micrometer.

A voltage applied to the common electrode **43** is zero.

A control pulse voltage Vc-on of +250V is applied to the control electrode **42** when the toner T is allowed to pass through the toner passage hole **41** (i.e., a turn ON condition). Whereas a control pulse voltage Vc-on of 0V is applied to the control electrode **42** when the toner T is prohibited to pass through the toner passage hole **41**. Although a bias voltage Vp applied to the backside electrode **5** depends on the interval between the toner control device **4** and the printing medium **3**, but preferably ranges from +200 to +1500V of the DC voltage. In the embodiment of FIG. **4**, the interval between the toner control device **4** and the printing medium **3** is 0.3 mm, while a voltage DC+800V is applied to create potential inclination, so that negatively charged toner is attracted to the surface of the printing medium **3**.

When prescribed voltages are applied to the respective electrodes **11**, **42**, **43**, and **5** as designated in the above-mentioned relation, and accordingly, negatively charged toner is allowed to pass through the toner passage hole **41** as shown in FIG. **4**A, lots of the electric flux lines flowing from the electrode **5** on the printing medium **3** side that receives the largest positive voltage pass through the toner passage hole **41** and reach the toner bearing member electrode **11** that receives the smallest voltage of −200V.

Specifically, the electric flux lines **10** flowing from the electrode **5** and passing through the toner passage hole **41** reaches the lowest electrodes **11** of −200V at two positions.

Accordingly, either negatively charged toner in the cloud state on the toner bearing member **1** or toner existing in the vicinity of the bearer electrode receiving the voltage of −200V passes through the toner passage hole **41** along the electric flux lines **10**, so that the toner T can soar on the surface of the printing medium **3**.

Whereas when the toner T is to be prohibited to pass through the toner passage hole **141** (i.e., an OFF condition) as shown in FIG. **4**B, −200V is applied to the control electrode **42**. Although, the lower voltage side of the electrode **11** is similarly −200V, and electric flux lines flowing from the electrode **5** entirely enter the control electrode **42** approximately arranged thereto. Accordingly, the toner on and above the surface of the toner bearing member **1** does not soar toward the electrode **5**. The voltage applied to the control electrode **42** in this prohibiting condition (i.e. the OFF condition) is not necessarily the same as that of the lower voltage side of the electrode **11**. Specifically, the toner T can be blocked (the OFF condition) as far as a condition that the electric flux lines passing through the toner passage hole **41** do not reach the surface of the toner bearing member **1** is met.

Now, one example of the image forming apparatus is described with reference to FIG. **5**. As shown, the image forming apparatus forms a color image by providing four items of units as mentioned above while making clouds of four component color toner of yellow, magenta, cyan, and black, and executing ON/OFF control using a toner control device.

Specifically, the image forming apparatus includes four toner supply units **100**Y, **101**M, **101**C, and **101**K (hereinafter collectively referred to as a toner supply unit **100** when color is not important) which make and supply four clouds of component color toners of yellow, magenta, cyan, and black. Between the respective toner supply units **100** and an intermediate transfer printing medium **103**, there is arranged a toner control device **104** having similar configuration to the toner control device **4** of the above-mentioned embodiment.

The intermediate transfer-printing medium **103** is wound around two rollers **132** and **133** and circulates n a direction as shown by an arrow. A backside electrode **105** serving as a printing medium side electrode is arranged corresponding to the respective toner supply units **100** on the backside (e.g. an inner side) of the intermediate transfer printing medium **103**. Further, a cleaning unit **135** is provided to remove toner remaining on the intermediate transfer printing medium **103** after a transfer process.

The toner supply unit **100** includes a cylindrical toner bearing member **101** having the similar configuration as the toner bearing member **1** which includes plural electrodes **111** arranged side by side to receive voltages for making toner in a cloud state. The toner supply unit **100** also includes a toner-replenishing roller **113** that rotates and replenishes the toner to the toner bearing member **101**, and a blade **114** that determines an amount of toner on the toner-bearing member **101**.

In this example, the toner is repelled from the toner replenishing roller **113** to the toner bearing member **101**, because the toner is charged by friction caused between the toner replenishing roller **113** and that the toner bearing member **101**. Further, the blade **114** arranged downstream of the toner replenishing roller **113** makes a thin lay of a prescribed amount of the toner on the surface of the toner bearing member **101** while stabilizing a charge amount thereof.

Then, when the toner control device **104** executes turn ON/OFF control in accordance with presence of an image, the toner supplied by the toner supply unit **100** soars on the intermediate transfer printing medium **103**, so that a color toner image is formed on the intermediate transfer printing medium **103**.

A sheet feeding section **151** is arranged at a lower part to accommodate printing sheets **150**. The printing sheet **150** is fed by a pickup roller **152** from the sheet feeding section **151** and receives a toner image formed on the intermediate transfer printing medium **103** at a position of a transfer roller **153** opposing the roller **132** winding the intermediate transfer printing medium **103**. A fixing unit **160** fuses the toner onto the printing sheet **150**. The printing sheet is then ejected.

Even not shown, due to application of a positive bias to the transfer roller **153** arranged on the backside of the printing sheet **150**, a toner image is transfer onto the surface of the printing sheet **150** from the intermediate transfer printing medium **103**. As mentioned above, the cleaning unit **135** removes the toner remaining on the intermediate transfer printing medium **103** therefrom, and the next image formation is prepared.

As mentioned, the image forming apparatus employs the intermediate transfer printing system that forms four color images on the intermediate transfer printing medium and transfers the same onto the printing sheet fed from the sheet feeding section. In such an intermediate transfer printing medium system, it is easy to maintain a constant interval between the printing surface (i.e. an image formation surface at which toner arrives) and the toner control device, so that a high quality image can be obtained even when a toner slowly soars. Further, the printing surface can be smooth avoiding accumulation of electric charge and a change of voltage, if a cubic resistance is adjusted. An image forming apparatus that directly executes printing by controlling clouded toner to turn on/off is generally highly sensitive to a voltage. Thus, the image forming apparatus tends to change image quality in response to a change of a printing surface bias voltage. However, according to the above-mentioned configuration, a high quality color image can be obtained.

Now, another image forming apparatus is described with reference to FIG. **6**. As shown, the image forming apparatus directly forms an image on a printing sheet as a printing medium. Specifically, a printing sheet **150** is fed from the sheet feeding section **151** and is electrostatically attracted to a sheet conveyance belt **161**. The printing sleet **150** is conveyed through the toner supply unit **100**. Then, a color image is directly formed on the printing sheet **150** by the ON/OFF control of the toner control device **104** in accordance with presence of an image.

The sheet conveyance belt **161** is made of polyimide or the like and is circulated being wound around two rollers **162** and **163** in a direction as shown by an arrow. The sheet conveyance belt **161** is charged by a charge device, such as a charge roller, etc., not shown, and electrostatically absorbs and conveys the printing sheet **150**. A guide **164** and a registration roller **165** for guiding the printing sheet **150** from the sheet feeding section **105** to the sheet conveyance belt **161** are arranged.

Since the sheet conveyance belt **161** and the printing sheet **150** are sandwiched between the toner control device **104** and the backside electrode **105**, it is difficult to significantly narrow an interval between the toner control device **104** and the backside electrode **105**. However, an image quality rarely deteriorates with toner scattering during toner transfer. Because, a transfer process is omitted and the color image is directly formed on the printing sheet **150**.

Further, since the belt cleaning mechanism of FIG. **5** or the like is not needed, a small and low cost image forming apparatus can be obtained. Since a toner cloud is made, and the toner can be guided under a low printing surface bias (i.e., backside electrode bias), an arriving speed of the toner at a sheet surface can be decreased. As a result, an image forming apparatus produces a high quality image while avoiding scattering of the toner.

Now, an exemplary toner bearing member employed in the above-mentioned image forming apparatus is described with reference to FIGS. **7**A and **7**B. As shown, plural comb sate electrodes are arranged on the surface of the toner-bearing member **101**. Specifically, two phase use electrodes are provided, in which every other electrodes portions are connected at one ends, while two phase pulses having a different phase from the other by 180 degree as shown in FIG. **8** are applied. Thus, a two-phase electric field is created on the toner bearing member such that attraction and repulsive motions repeat between neighboring electrode portions.

Specifically, plural comb state electrodes **111** of A and B phase uses (**111**A and **111**B) are arranged on a surface of an insulation substrate **101**A. A surface protection layer **101**B is further arranged on the plural electrodes **111**. The comb state electrode portions **111**A and **111**B are arranged in parallel to each other with a fine pitch in a toner conveyance direction. The both sides of the portions are connected to a two-phase pulse generation circuit, not shown, arranged outside via common bus lines **111**Aa and **111**Ba.

Frequencies of pulse voltages applied to the electrodes **111**A and **111**B are 0.5 to 7 kHz. The pulse voltages each include a DC voltage as a bias. Respective wave heights of the pulse voltages are preferably from ±60 to ±300V in accordance with a width and an interval of the electrode portions. When the two-phase electric field is used, toner repeatedly soars being repelled and attracted, thereby reciprocates between the neighboring electrode portions in response to switching of a direction of a neighboring electric field. At the same time, the toner-bearing member **101** rotates in a toner conveyance direction.

In this way, a cloud making device that causes toner to soar on the surface of the toner-bearing member **101** member and includes plural electrode portions arranged at a prescribed interval while extending in a direction perpendicular to the toner conveyance direction on the surface of the toner-bearing. Thus, when voltages are applied to the respective electrodes, the neighboring electrodes alternately attract and repel toner therebetween repeatedly, so that the toner is clouded and conveyed as the toner-bearing member rotates. Thus, the toner can be stably conveyed over the surface of the toner-bearing member **101** avoiding changing quality, and as a result, an image forming apparatus can be reliable.

Now, another exemplary toner bearing member employed in the image forming apparatus is described with reference to FIGS. **9**A and **9**B. As shown, plural electrodes are provided on the surface of the toner-bearing member **101**. All of electrode portions on a surface layer are connected with each other. A conductive substrate electrode **111**B arranged on a lower layer via an insulation layer. Two-phase pulses having a different phase from the other by 180 degree are applied between these electrodes **111**A and **111**B as shown in FIG. **8**. Thus, a toner bearing member repeats attraction and repelling of toner on a reciprocal basis in an electric fields created by the surface layer side electrode and the lower layer conductive substrate electrode.

Specifically, as the plural electrodes, the toner bearing member **101** of this embodiment includes the A-phase use electrode **111**A arranged on the surface of an insulation substrate **101**A, the (solid) flat conductive B-phase use electrode **111**B arranged on the lower surface of the insulation substrate **101**B, and a protection layer **101**B arranged on the surface of the electrodes **111**A as in FIG. **7**. The surface side electrode **111**A includes portions arranged with a fine pitch in a toner conveyance direction side by side. The both sides of these portions are connected to a two-phase pulse generation circuit, not shown, arranged outside via a common bus line **111**Aa.

A frequency of each of the two-phase pulse voltages is preferably from 0.5 to 7 kHz. The pulse voltage includes a DC voltage bias and a wave height of preferably from ±60 to ±300V. Thus, the pulse voltage is applied in accordance with a width and an interval of the electrode portions as described with reference to FIG. **7**. Thus, toner repeatedly soars between the surface layer side electrode portions **111**A in response to switching of the two-phase pulse when the two-phase electric field is used. At same time, the toner-bearing member **101** rotates in a toner conveyance direction.

The above-mentioned insulation substrate **101**A is made of insulation material, such as rein, ceramics, etc. Otherwise, an insulation coat, such as SiO_2, etc., can be coated onto a conductive substrate made of aluminum or the like. Yet otherwise, flexible material, such as polyimide, etc., can be used. Further, to produce the electrode **111**, conductive material, such as Al, Ni—Cr, etc., having a thickness of from 0.1 to 1 micrometer is coated onto the base substrate and then shaped into an electrode pattern using a photolithography technology or the like. Otherwise, a copper foil is laminated or patterned using a photolithography after being plated. The lower layer conductive substrate electrode **111**B of FIG. **9** is preferably made of conductive material, such as Al, Ni—Cr, etc.

The surface protection layer **101**B having a thickness of from 0.5 to 2 micrometer made of such as SiO_2, TiO_2, TiN, Ta_2O_5, etc., can be vaporized and coated. Otherwise, organic material, such as polycarbonate, polyimide, methyl methacrylate, etc., having a thickness of form 2 to 10 micrometer is printed and coated and is then heated and hardened.

In thus configured toner bearing member **101**, when a soaring use pulse is applied from a drive circuit and a soaring electric field is created, toner charged on the toner bearing member **101** receives repelling and attraction forces, and the toner soars up and down, and is conveyed in a traveling wave direction.

Now, an exemplary toner supply unit **100** employed in the above-mentioned image forming apparatus is described with reference to FIG. **10**. As shown, the toner supply unit **100** uses two-component printing agent including magnetic carrier and non-magnetic toner. A printing agent containing section **201** is separated into two chambers **201**A and **201**B communicated with each other by a printing agent passage, not shown, arranged at both ends in the toner supply unit **100**. The two component printing agent accommodated in the printing agent containing section **201** is conveyed therein being stirred by stir conveyance screws **202***a* and **202**B arranged in the respective chambers **201***a* and **201**B.

A toner replenishment inlet **203** is arranged in the chamber **201**A. Toner is replenished from a toner containing section, not shown, via the toner replenishment inlet **203** into the printing agent-containing section **201**. The printing agent-containing section **201** includes a toner density soar, not shown, that detects permeability of the printing agent. Thus, when toner density decreases in the printing agent containing section **201**, fresh toner is replenished thereto via the toner replenishment inlet **203**.

At a position opposing the stir conveyance screw **202**B, there is arranged a magnetic brush roller **204** as a toner replenishing roller. Magnet is secured inside the magnetic brush roller **204**. Thus, the printing agent in the printing agent-containing section **201** is lifted up onto the surface of the magnetic brush roller **204** by a magnetic and rotation force of the magnetic brush roller **204**. A printing agent layer thickness-determining member **205** is arranged opposing the magnetic brush roller **204** at a position downstream than a section where the toner is lifted up.

The printing agent lifted up at the lifting up position is smoothed by the printing agent layer thickness determination member **205** to have a prescribed thickness. The printing agent passing through the printing agent layer thickness determination member **205** is conveyed to a position opposing the toner bearing member **101** as the magnetic brush roller **204** rotates. The magnetic brush roller **204** receives a supply bias from a first voltage application device **211**.

The electrode **111** of the toner-bearing member **101** receives a voltage from a second voltage application device **212** as shown in FIGS. **7** and **9**. Accordingly, an electric field is created between the toner bearing member **101** and the magnetic brush roller **204** by the first and second voltage applying device **211** and **212**. Thus, the toner receives an electrostatic force from the electric field and separates from the carrier, thereby moving to the surface of the toner-bearing member **101**. The toner arrived at the surface of the toner bearing member **101** is made into a cloud state by the electric field, which is created by the voltage applied to the electrode **111** from the second voltage applying device **212**. Thus, the toner is conveyed by either rotation or a traveling wave electric field of the toner-bearing member **101**.

The toner conveyed to the position opposing the toner control device **104** selectively soars toward the printing medium by a toner passage ON/OFF control electric field, which is created by the control electrode **42**, so that a dot printing of the toner is controlled.

Now, an exemplary toner supply unit **100** employed in the above-mentioned image forming apparatus is described with reference to FIG. **11**. As shown, the toner supply unit **100** uses one component-printing agent including non-magnetic toner. The toner is accommodated in a print agent-containing section **201**. The toner is charged by friction created between a charge roller **220** and a toner-replenishing roller **113**, and is lifted up onto the toner-replenishing roller **113** due to the electrostatic force. The toner on the toner replenishing roller **113** is made into a thin layer by a printing agent layer thickness determination member **205**, and is conveyed to a position opposing the toner bearing member **101** as the toner replenishing roller **113** rotates.

At this moment, a supply bias is applied to the toner-replenishing roller **113** by the first voltage-applying device **221**. The second voltage-applying device **222** applies a voltage to the electrode **111** of the toner-bearing member **101**. Accordingly, an electric field is created between the toner-bearing member **101** and the toner-replenishing roller **113** by the first and second voltage applying devices **221** and **222**. Thus, the toner receives an electro static force from the electric field and separates from the toner-replenishing roller **113** and moves to the surface of the toner-bearing member **101**.

Similar to the above-mentioned example, the toner arriving at the surface of the toner-bearing member **101** is made in to a cloud state by the electric field, which is created by the voltage applied to the electrode **111** from the second voltage-applying device **222**. Then, the toner is conveyed by rotation and the traveling wave electric field of the toner-bearing member **101**.

Then, the toner conveyed up to a position opposing the toner control device **104** selectively soars due to the toner passage ON/OFF control electric field of the control electrode **42**, so that dot printing of the toner is controlled.

In the respect toner supply units **100**, the toner not contributed to printing is further conveyed by the toner-bearing member **101** and is collected by a collecting device, not shown, from the surface of the toner-bearing member **101**. The collected toner is again returned to a printing agent collection section **201** and circulates within the toner supply unit **100**.

Although the negatively charged toner is used in the above, a positively charged toner can be used.

Now, exemplary influence of a change of a gap between the toner bearing member having a prescribed surface curvature and the almost flat control electrode of the control device is described with reference to FIG. **12**.

As shown, the toner-bearing member **1** and the control device **4** are arranged opposing each other. Eight lines each having prescribed toner passage holes **41** in a widthwise direction are arranged in a moving direction of the printing medium **3** on the toner control device **4**. When a pixel is printed by eight dots of 600 dpi, an interval between nozzle lines is 0.339 mm and a distance Ls from first to eight nozzle lines is 2.37 mm, for example.

When a space distance at a center between the fourth and fifth lines is represented as G**0**, where the toner control device **4** most approximates the toner bearing member **1**, that at a first or eight line is represented as G**1**, a diameter of the toner bearing member **1** is 15 mm, and such G**0** is 200 micrometer, G**1** almost amounts to 290 micrometer with 45% increase of the smallest space distance.

Thus, the electric flux lines are loosely narrowed and a traveling distance of the toner increases at the first and eighth lines of the toner passage hole **41**, and accordingly, an amount of the passage toner arriving at the printing medium decreases down to less than that on the fourth and fifth lines. Thus, density accordingly decreases in comparison with that through the fourth and fifth lines.

An exemplary relation between a change of the gap G and a traveling amount of toner obtained through an experiment is now described with reference to FIG. **13**. The relation represents toner traveling amounts measured by changing an amount of the gap by −100 micrometer (to be 100 micrometer), 0 (to be 200 micrometer), and +100 (to be 300 micrometer). As shown, the value 76 mg/1,000 dot obtained when the change amount is 0 (i.e., the gap is 200 micrometer at G**0**) decreases down to 34 mg/1,000 dot when the change amount is +100 (i.e., the gap is 300 micrometer). Thus, when the change amount is about 90 micrometer at G**1**, it is supposed based on the above-mentioned liner relation that the value decreases down to about 0.38 mg/1000 dot as being 50% decrease in comparison with a case when the change amount is zero.

Now, an exemplary control section according to one embodiment of the present invention is described with reference to FIGS. **14** and **15**.

As shown, this exemplary control section includes the toner control device **4** that includes eight lines of toner passage holes **41** in the moving direction of the printing medium. In each of the lines, the plural toner passage holes **41** are formed at a prescribed interval in the widthwise direction as mentioned corresponding to a prescribed printing density.

The control section includes a CPU **501** that generally controls the image forming apparatus, a ROM **502**, and a RAM **503**. Also included are an image processing ASIC **504**, a periphery control circuit **505**, an USB I/F **506** as an external Image forming apparatus PSU **507**, and a prescribed number (e.g. eight) of counters **511** corresponding to a number of lines of the toner passage holes **41**. Further included is a driver IC **530** as shown in FIG. **15** and the like. The counters **511** are typically illustrated for the first to the fourth lines among the eight lines.

As shown in FIG. **16**, the ROM **502** stores a pulse width data table that includes pulse width data of a control pulse Vc to be applied to the control electrodes **42** for the toner passage holes on the first to eighth lines. The pulse width of the control pulse Vc controls the toner passage hole **41** to allow the toner to pass through.

The driver IC **530**, corresponding to the drive circuit **7**, includes a shift register that inputs serial data transmitted from the image processing ASIC **504** in accordance with a shift clock, a latch circuit **532** that latches data stored in the shift register **531** based on a latch signal transmitted from the image processing ASIC **504**, and an AND circuit **533** that applies logical multiplication to data transmitted from the latch circuit **532** and control pulses P**1** to P**8** transmitted from the counters **1** to **8**. Also included are a DC high voltage power supply **534** turned on and off by an output of the AND circuit and a high voltage switch circuit **535** receiving an input of a high voltage (e.g. DC 200V) from the DC high voltage power supplies **534**. An output from the high voltage switch circuit **535** is applied to the control electrode **42** of the toner control device **4** as the control pulse Vc.

When the control section receives printing data from a prescribed external apparatus via the USB I/F **506**, the CPU **501** stores the printing data one after another in the RAM **503**. When the data is entirely received, the CPU **501** instructs the image processing ASIC **504** to reorder printable data. Thus, the image processing ASIC **504** takes in the printing data from the RAM **503** without intervention of program of the CPU **501**, and entirely stores the same in a buffer included in the ASIC while automatically reordering thereof.

When the reordering is completed by the image processing ASIC **504**, the peripheral control circuit **505**. Causes a sheet feed motor **521**, a toner bearing member use drive motor **522**, a printing medium conveyance use motor, a fixing motor, and a various high voltage power supplies **524** to be operable.

When the printing medium reaches a prescribed position, a sensor inputs a detection signal to the peripheral control circuit **505** and the image processing ASIC **504** is started. The image processing ASIC **504** transfers serial data and a shift clock to the driver IC **530** to execute printing. The driver IC **530** stores the data transferred in the shift register **531** thereof.

At this moment, the CPU **501** reads at same time the pulse width data of from the first to eighth lines from the pulse width data table stored in the ROM **502** and transfers the same to the counters **1** to **8**, respectively. Upon completing printing data transfer to the driver IC **530** for all of the control electrodes, the image processing ASIC **504** stops outputting the serial data and the shift clock, and outputs the latch signal. Thus, the driver IC **530** shifts all of the data from the shift register **531** to the latch circuit **532** to be latched therein.

Subsequently, the CPU **501** causes the counters **1** to **8** to start counting up. Simultaneously, outputs (i.e., control pulses P**1** to P**8**) of the counters **1** to **8** become high (H) and keep the level until the pulse width data previously transferred from the CPU **501** to the counter **511** accords with a number of the clocks.

For example, as shown in FIG. **14**, numerals **256**, **230**, **205**, and **177** are set to the counters **1** to **4**, respectively. When, the pulse width data accords with the number of clocks, the counters **1** to **8** stop operating and changes the output to a level "L". If one clock is represented by 1 microsecond, widths of the control pulses P**1** to P**4** are calculated as 256, 230, 205, and 177 microsecond, respectively. These control pulses P**1** to P4 are inputted to the driver IC **530** and are subjected to the logical multiplication in the AND circuits **533** with the outputs of the latch circuit **532**.

The outputs of the AND circuits **533** are inputted to the high voltage switch circuits **535**, and are outputted with an output setting value (e.g. a wave height value 200V) as the high voltage control pulses Vc having pulse widths of the control pulses P**1** to P**4**, respectively. The high voltage control pulses Vc are provided to n number of the control electrodes **41** (i.e., electrodes **1** to n).

In this example, since the electrodes **1**, **5**, and **9** are included on the first line, their control pulses Vc include 526 microsecond. Similarly, the electrodes belonging to two to fourth lines, their control pulses Vc include 230, 205, and 177 microsecond, respectively. In such a situation, the fifth, sixth, seventh, and eighth lines have the same value as the fourth, third, second, and first lines, respectively.

In this way, in proportion to a decrease amount of toner, a width of the control pulse Vc causing the toner to pass (i.e., toner passage ON condition) becomes longer, and accordingly, the control pulse Vc is applied longer in the first and eighth lines, where the space distance is largest. Specifically, by relatively decreasing the width of the control pulse Vc in the fourth and fifth lines where the space distance is smallest, deterioration of conveyance efficiency of the toner is corrected as a whole. Thus, density change created depending on a position of a control electrode line can be suppressed and a fine image can be obtained. As a result, a high-speed printing can be achieved without decreasing printing speed.

In this way, control pulses having different width, for example, are applied per one or plural lines of toner passage holes on the toner control device to control an amount of toner passing therethrough when clouded toner is moved from the toner bearing member to the printing medium side through the toner passage hole. Thus, the amount of the toner passing through the respective toner passage hole lines in the printing medium moving direction can be equalized. As a result, an image quality can be improved enabling the high-speed printing.

Now, another exemplary pulse width data table including data of a pulse width is described with reference to FIG. **17**. In this example, a pulse width of the pulse width data table is changed in accordance with a printing line speed. Specifically, when the printing line speed is decreased to half, the pulse width data generally becomes almost twice, because a time for completely filling a prescribed area with toner takes about twice. However, influence of cloud toner behavior and air resistance of toner decrease, practically, and an amount of the toner increases. Accordingly, as shown in FIG. **17**, when the line speed is 168 mm/s on the first line, the pulse width becomes 256 microsecond, where as when the line speed is 84 mm/s, the pulse width becomes 492 microsecond, and is 1, 9 times as being less than twice.

The pulse width for each of the lines is determined as shown in FIG. **18**. Specifically, as shown, an exemplary ratio of an amount of toner that passes through a toner passage hole **41** on a line other than the central fourth and fifth lines to that through the toner passage hole **41** on the fourth and fifth lines is calculated and determined. Then, the pulse width provided to each of the lines is changed in accordance with the toner ratio.

Now, yet another embodiment is described with reference to FIGS. **19** to **21**, in which only the first to fourth lines are illustrated. As shown, a control pulse having a different wave height is provided per one or more lines. To change the wave height, the ROM **502** stores a table listing wave height data of the control pulse corresponding to a line as shown in FIG. **21**.

Further, instead of the counters of the first embodiment, DACs (i.e., a D/C converter) **541** are provided to apply D/A conversion to wave height data and outputs resulting data of respective control pulse voltages V**1** to V**8**. Further, instead of the DC high voltage power supplies, high voltage amplifiers **542** that receive the control pulse voltages V**1** to V**8** and output voltages Vp**1** to Vp**8** each having a prescribed wave height are employed. The outputs voltages Vp**1** to Vp**8** are then inputted to high voltage switch circuits **535**. The high voltage switch circuits **535** receive outputs from the AND circuits **533**, each of which is obtained by multiplying a strobe signal from the image processing-ASIC **504** and latch data of the latch circuit **532**.

In this example, an amount of toner passing through the toner passage hole **41** is controlled by changing the wave height per line (or prescribed plural lines) while maintaining a pulse width of the control pulse Vc to be a constant value such as 200 ms. Specifically, this example corrects a change of conveyance efficiency of the toner caused by the space distance between the toner-bearing member **1** and the toner passage hole **41**.

Now, another exemplary wave height table is described with reference to FIG. **22**. As shown, a wave height included in a wave height data table is changed per printing line speed. Specifically, when the printing line speed is decreased to half, the wave height data generally becomes almost twice, because a time for completely filling a prescribed area with toner takes about twice. However, influence of flare behavior and air resistance of toner decreased, and an amount of the toner increases practically.

Instead of the negatively charged toner, positively charge toner can be utilized.

Obviously, numerous additional modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the present invention may be practiced otherwise than as specifically described herein.

ADVANTAGE

According to one embodiment of the present invention, an amount of toner passing through each of the respective toner passage holes arranged in a printing medium moving direction can substantially be equalized while achieving high speed and high quality image formation.

What is claimed is:

1. An image forming apparatus, comprising:

a toner-bearing member configured to bear toner and make the toner clouded thereon;

a toner passage control device including at least two widthwise lines of toner passage holes in a printing medium conveyance direction, each of said toner passage holes including a control electrode configured to control passage of the toner through each of the toner passage holes toward a printing medium; and

a control pulse providing device configured to provide a control pulse to the control electrode to operate;

wherein said control pulse applied to the control electrode of the one of the at least two lines is different from that applied to the control electrode of the other one of the at least two lines.

2. The image forming apparatus as claimed in claim **1**, wherein said control pulse is different from the other by including at least one of a different pulse width and a different pulse wave height.

3. The image forming apparatus as claimed in claim **1**, wherein said control pulse corresponds to a printing line speed.

4. The image forming apparatus as claimed in claim **1**, wherein said printing medium includes a printing sheet, further including a sheet opposing electrode arranged on a backside of the printing sheet and configured to receive a bias directing toward the printing sheet.

5. The image forming apparatus as claimed in claim **1**, wherein said printing medium includes an intermediate transfer medium, further including a medium opposing electrode arranged on a backside of the intermediate transfer medium and configured to receive a bias directing toward the intermediate transfer medium.

6. The image forming apparatus as claimed in claim **1**, further comprising a color image formation device configured to form and overlap toner images of different colors and configured to form a full-color image on the printing medium.

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